POWER

Vol. 39 NEW YORK, FEBRUARY 17, 1914 No. 7

Smoke Means Waste

15 to 30% WASTE
SMITH CO. SONS
COAL BILL
He Has His Sign Wrong – It Is A Smoke Factory
He Runs A Gas Producer – But He Wastes The Gas
Yes, There's A Fine Bunch Of Profits Going Up That Stack.
I'm Glad We Don't Work Down Here. Think Of All That Soot.
Suggested by M.C. Huyette
POWER

APPARENT TO ALL BUT THE ONE MOST CONCERNED

The Lardner's Point Pumping Plant

By Warren O. Rogers

SYNOPSIS—Philadelphia, in 1801, built the first water-works system in the United States at a cost of $220,360. This city has the distinction of operating the largest pumping water-works plant in the world. The latest distributing station is the Lardner's Point plant, with a normal capacity of 240,000,000 gal. of water per 24 hr. There are twelve 20,000,000-gal. vertical triple-expansion pumps in two stations, supplied with steam by fourteen 500-hp. water-tube boilers.

The city of Philadelphia enjoys the distinction of having operated the first steam-pumped water system in the United States and also of operating the largest pumping plant in the world. There are two rivers from which to draw the water, the Schuylkill and Delaware, the latter river furnishing at present approximately 70 per cent. of the city's water consumption.

The first pumping engine used had a capacity of 962,520 gal. of water per 24 hr. with a consumption of 55 bu. of coal. The Lardner's point pumping plant consists of two separate stations, with twelve 20,000,000-gal. pumps of modern design for high-service work.

The old Center Square pumping-plant building, a section of which is shown in Fig. 1, was constructed of marble and was 60 ft. square at the bottom and 25 ft. high. The upper part was built in circular form, having a diameter of 40 ft. and being 60 ft. high. It was surmounted by a dome through the center of which the stack from the boiler extended.

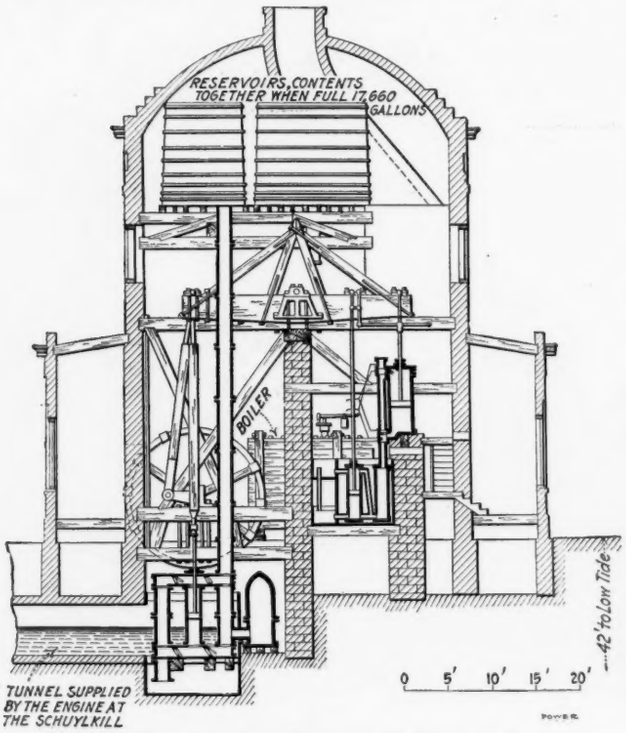

RESERVOIRS, CONTENTS TOGETHER WHEN FULL 17,660 GALLONS
BOILER
42 to low Tide
0 5' 10' 15' 20'
TUNNEL SUPPLIED BY THE ENGINE AT THE SCHUYLKILL
POWER

Fig. 1. Old Center Square Pumping Plant

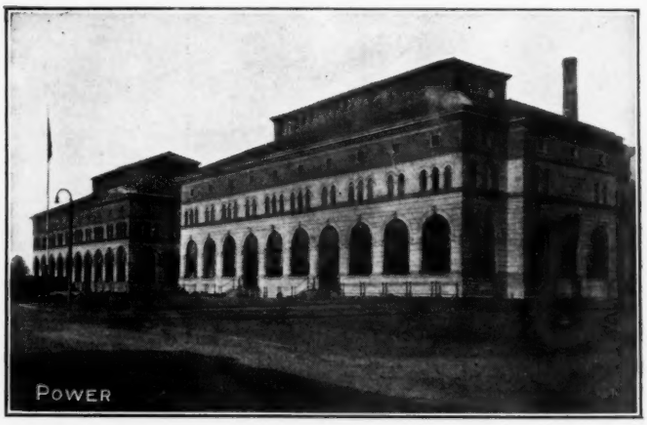


Fig. 3. Front View of Lardner's Point Station

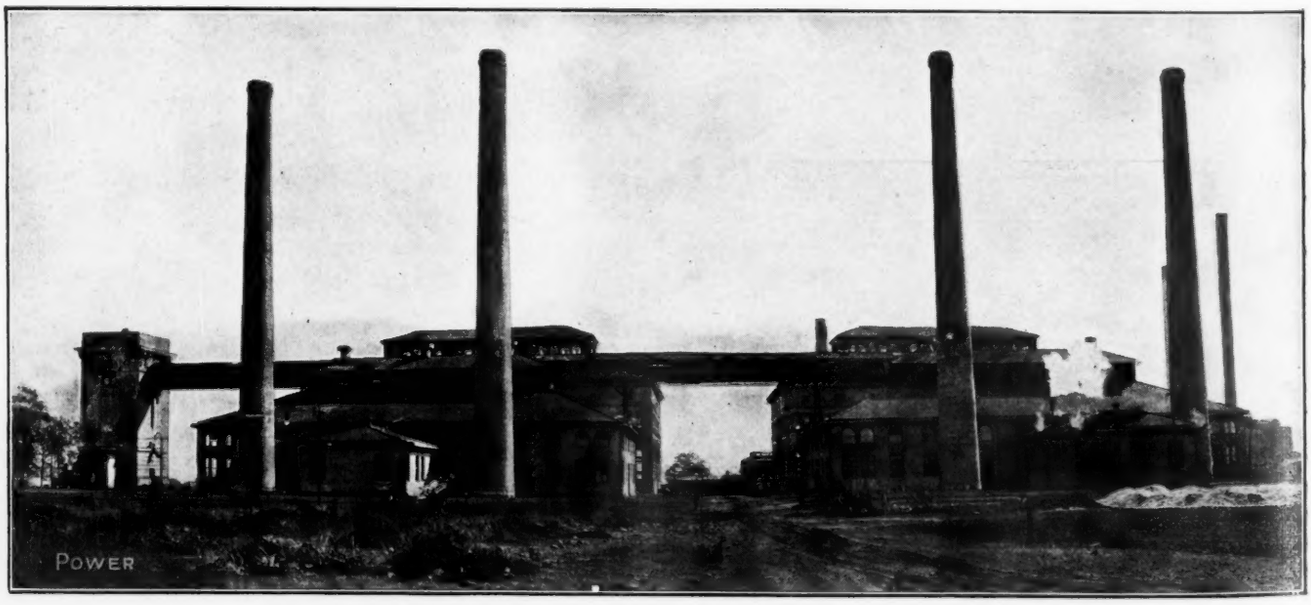


Fig. 2. Boiler-House Side of Pumping Station

When one considers the material of which the pumping engine and boiler was constructed, it is a matter of surprise that the apparatus had such a large capacity. For instance, all the levers, beams, flywheel, shafts and arms, cold-water pumps and cisterns were made of wood. Even the boiler was a $^{5}/_{7}$-in. white-pine box, 9 ft. high, 9 ft. wide and 15 ft. long, securely bolted through and braced on the outside. The boiler firebox was of wrought iron with cast-iron vertical flues. The main cylinder of the engine was cast in two pieces, united with copper, the joints being secured externally by a cast-iron band. Nearly four months were consumed in boring the cylinder. The force pumps were double-acting and were first used without air chambers.

The engine pumped water into two wooden tanks on top of the buidling, which were 50 ft. above the bottom of the brick tunnel leading from the Schuylkill pumping house, where a similar pump was in operation. These tanks held 17,094 gal. The engine was able to fill them in about 25 min., the same time being taken to exhaust them. Any disability of the pump meant a water famine in a few minutes.

The present pumping system of the city comprises four high-duty stations, three of which are on the Schuylkill River, and the other at Lardner's Point. The latter connects with the Torresdale conduit and pumps Delaware River water after it has passed through the filters at Torresdale. A description of the Torresdale plant and filter beds was published in POWER, Nov. 16, 1909, page 811. This plant contains seven 40,000,000-gal. centrifugal pumps and one 50,000,000-gal. unit, the water being pumped to the preliminary filtering beds and flowing by gravity to the final filters.

After the water has passed through the final filters it flows by gravity to a filtered water basin having a capacity of 50,000,000 gal. This filtered water is carried to the Lardner's Point pumping station through a conduit 13,807 ft. long and 10 ft. 7 in. in diameter. The conduit has an elevation at the entrance shaft of 127 ft. below the ground surface, but at the outlet end is 10 ft. higher, the rising grade being made to prevent air pockets.

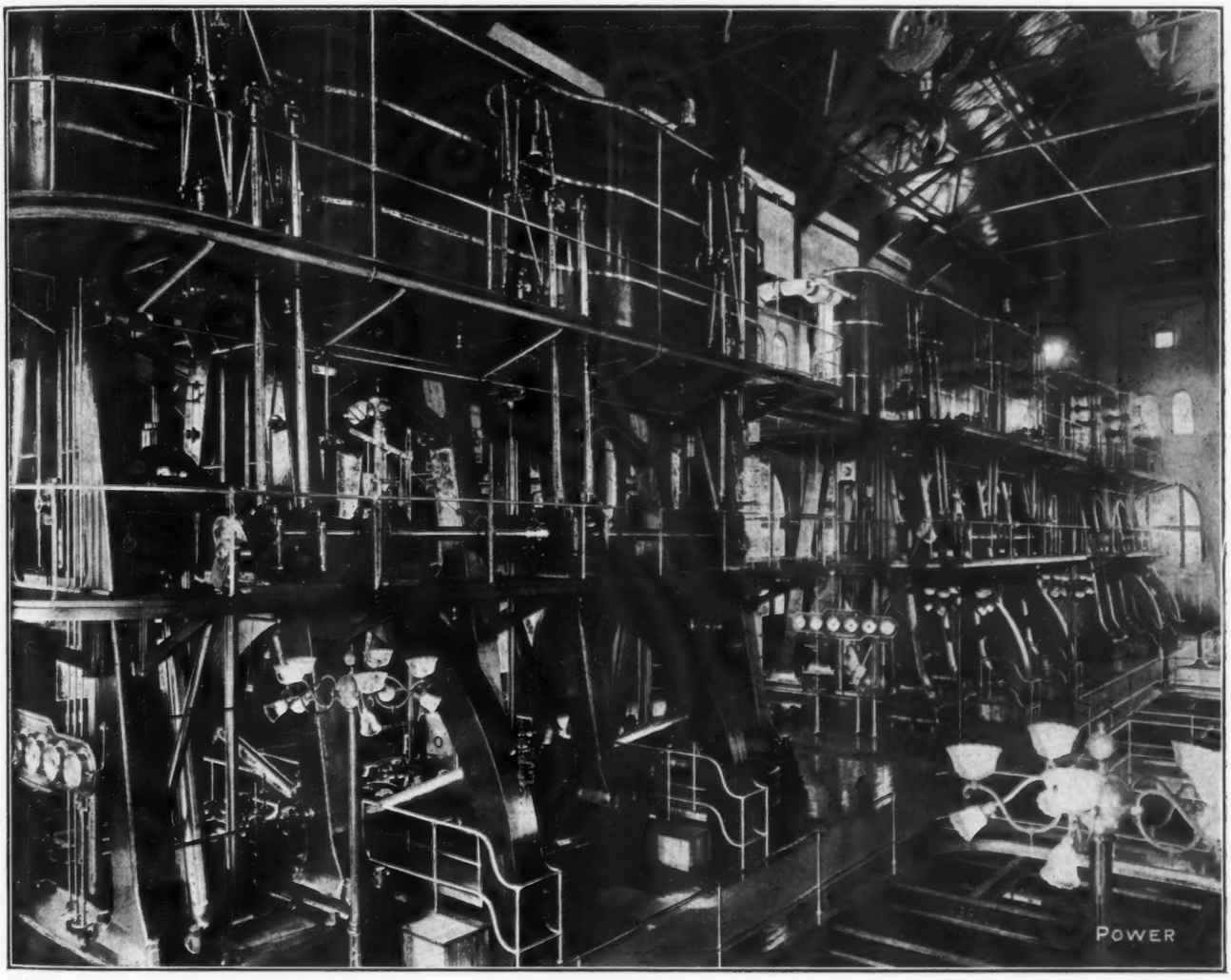


FIG. 4. PARTIAL VIEW OF PUMPING ENGINES IN NO. 2 PUMPING STATION

The pumping outfit at Lardner's Point consists of two plants, known as Nos. 2 and 3 stations. Rear and front views of the buildings are shown in Figs. 2 and 3, each building containing six vertical, triple-expansion pumping engines, each of 20,000,000-gal. capacity.

An interior view of each plant is shown in Figs. 4 and 5. The engine rooms are built separately from the two boiler houses and are 171 ft. long by 87 ft. wide and constructed of gray brick with granite and terra cotta trimmings. The roof coverings are of red tile.

The water ends of the pumps are in the basement, Fig. 6, under the floor of the engine room; the entire steam ends are above the floor level. The pump well is placed under the basement floor in the center of the building and extends the full length, being horseshoe-shaped in sections, 14 ft. in width, and constructed of reinforced concrete. Data relating to the engines in the two stations are as follows:

Each pump is fitted with a feed-water pump, a heater and an ejector condenser, one of the condensers being shown in Fig. 6. Water for condensing purposes, taken from the Delaware River, is returned to the river after passing through the condensers. The condenser air and water are handled by a bucket pump driven directly by the engine. In passing through the feed-water heater, the water is heated to 120 deg. F., then going to the

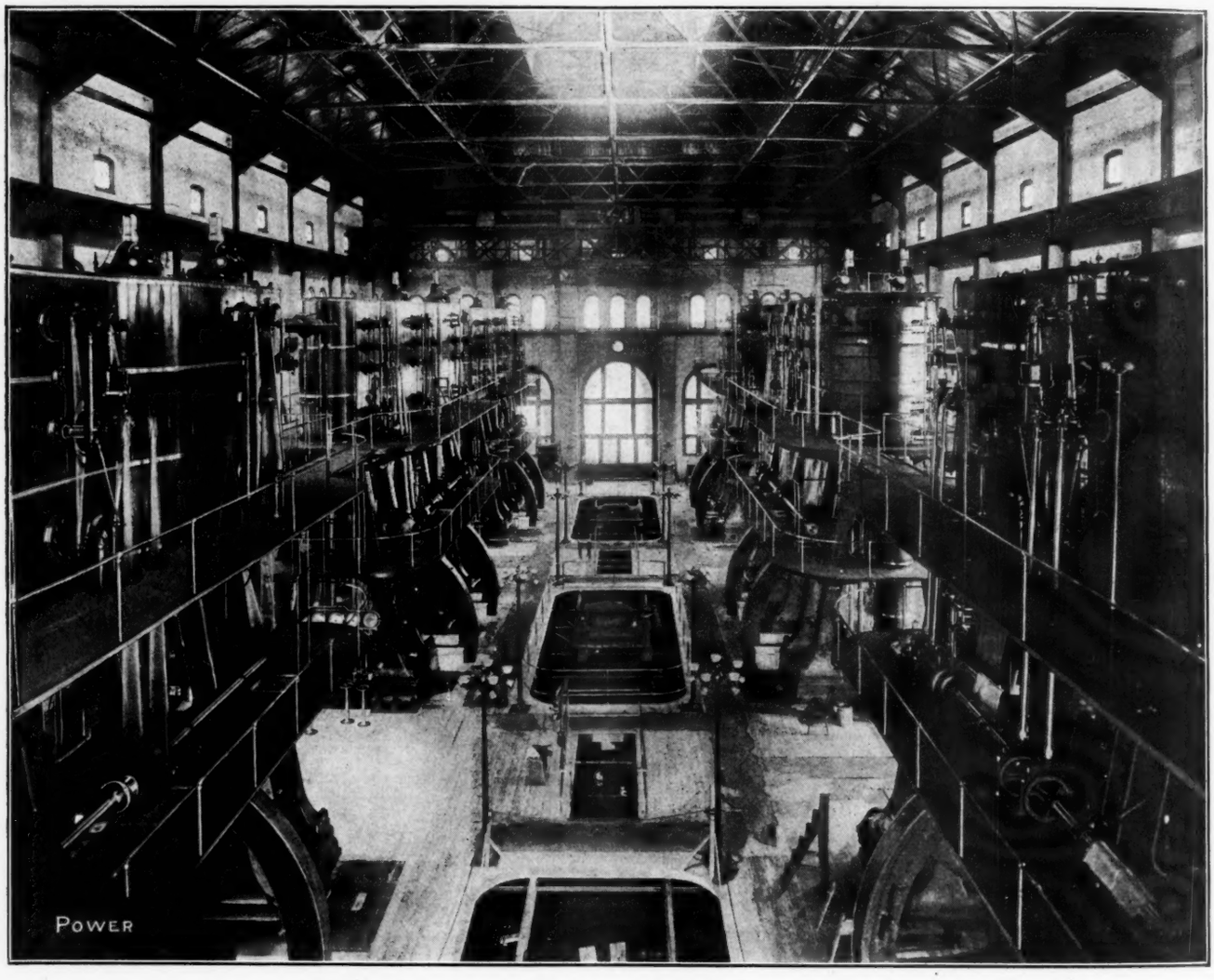


FIG. 5. PUMPING ENGINES IN NO. 3 PUMPING STATION

Nominal capacity of each engine, gal. daily			20,000,000
Number of r.p.m.			20
Stroke, ft.			5½
Piston speed, ft. per min.			220
	High	Intermediate	Low
Cylinder diameter	32″	60″	90″
Diameter piston rod	7½″	7½″	7½″
		First	Second
Receiver volume		205 cu.ft.	304 cu.ft.
Receiver heating surface		166 sq.ft.	304 sq.ft.
		Diameter	Length
Crosshead pins		12″	11″
Crank pins		12″	11″
Shaft bearings		17½″	32″
Shaft at center		20¼″	

Distance rods—Four, each 5-in. diameter.
Air pump—One 28-in. diameter, 66-in. stroke.
Feed pump—One 3¼-in. diameter, 66-in. stroke.
Feed water heater—One in exhaust, 308 sq.ft.
Flywheels—Two, 20-ft. diameter and weighing 32 tons each (approximate).
Throttle valve—8in. diameter.
Exhaust pipe—24¾-in. diameter.
Suction pipe—Main 42-in. diameter, branch 30-in. diameter.
Discharge pipe—Main 42-in. diameter, branch 30-in. diameter.
Suction injection—8-in. and 10-in. diameter.
Force injection—3-in. and 3½-in. diameter.
Overflow—18-in. diameter.
Diameter of plungers—33 in.

	No. 2 House	No. 3 House
Number of pump valves	960	864

economizers and boilers. A general view of the water piping and the position of the boilers and pumps in their respective buildings is shown in Fig. 7.

Fig. 8 is a partial plan view of No. 3 boiler room and piping. Two 10-in. steam mains run to the pumping plants. In No. 3 station each branch pipe has a steam separator close to the engine throttle. In No. 2, the main header in the basement contains a steam separator; the separators are all drained by traps. The cylinder jackets drain into a 2-in. pipe which discharges into a pump receiver, to be returned to the boilers by two 7 and 4½ by 8-in. duplex steam pumps. The steam pipes from the main header to the pumps are 6 in. in diameter, and are taken from the header, which is in the basement in both buildings, and run to the boiler houses through a tunnel. Fig. 9 shows the position of the steam header. The lower water main is for the condenser circulating water. Two 8 and 8 by 10-in. air pumps in the base-

ment of No. 3 pump house supply air at 105-lb. pressure for closing the top valves on the low-pressure cylinder.

In the basement there is a bypass between the suction and the discharge pipe of each pump, fitted with a relief valve. If anything obstructs the discharge line, water is discharged into the suction pipe. The large valves on the suction line are hydraulically operated.

All pumps discharge into city mains, but if the pressure exceeds the allowable pipe-line pressure, the excess water backs up into one of the reservoirs. If the pressure is reduced in the city main, water flows by gravity from the reservoir into the main, and in this way acts as a relief valve.

All pumps are equipped with an oiling system operated by compressed air. Oil is received by the carload and emptied into a 2500-gal. tank outside the building. This tank is subjected to an air pressure of 50 lb. and the oil is forced into two small galvanized-iron tanks suspended in the basement from the engine-room floor.

These small tanks are also kept under 50-lb. air pressure, which elevates the oil to the top of the engines through brass piping, from which point the oil flows by gravity to the bearings.

The water pressure on the pump intakes is 69 lb.; the steam pressure 175 lb. on the high-pressure cylinder and 12 lb. on the intermediate receiver. A vacuum of 15 in. is carried on the second receiver and of 28 in. in the condenser.

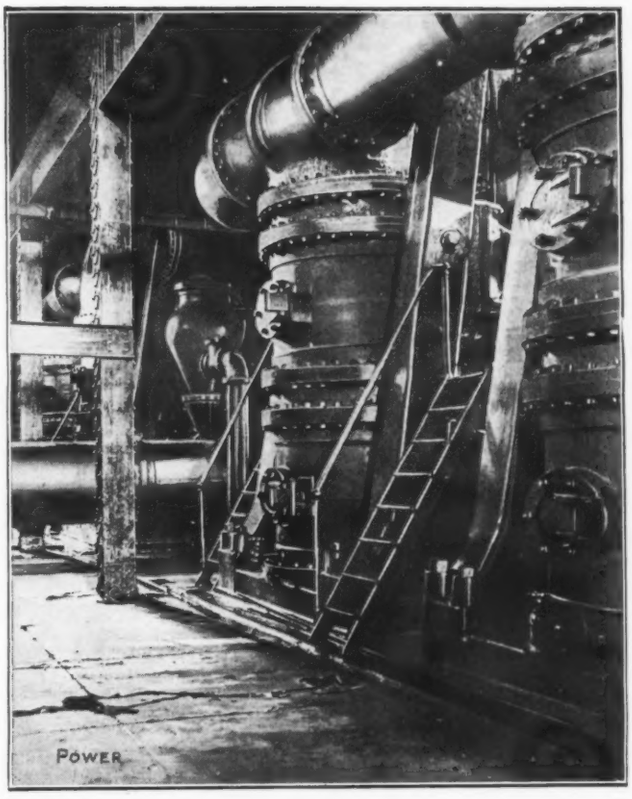


FIG. 6. WATER END OF PUMPS; ALSO JET CONDENSER

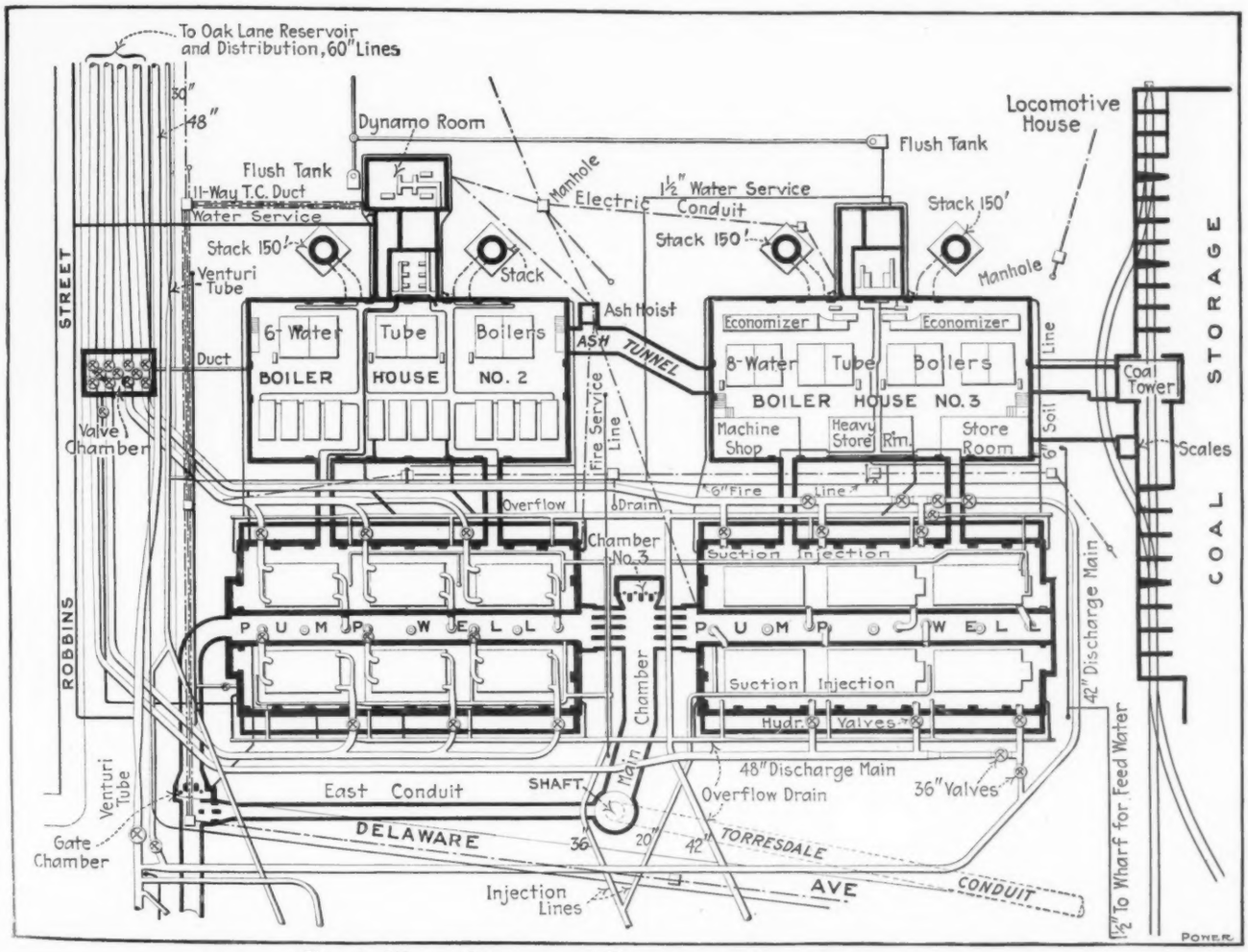


FIG. 7. WATER PIPING FOR NOS. 2 AND 3 PUMPING PLANTS

The pumps in the two pumping plants work against a head of 193 and 247 ft. Last year, these stations pumped 73,350,000,000 gal. of water, requiring 63,800 tons of coal, 15,000 gal. of engine oil, 14,600 gal. of cylinder oil and 7000 lb. of lubricating grease.

Boiler Houses

Both boiler houses of the new station are of the same general architecture; No. 2 boiler house contains six water-tube boilers of 500-hp. capacity each, equipped with mechanical stokers, and there are eight 500-hp. water-tube boilers equipped with mechanical stokers and two economizers in No. 3 boiler house. The piping of the boiler installation is shown in detail in Fig. 8. These boilers contain 252 four-inch tubes, 18 ft. long. The two steam drums are each 36-in. in diameter and are 21 ft. long.

The length of the stoker grate is 8½ ft. and the area is 102 sq.ft. The boilers are set in batteries of four each. The two 10-in. steam mains to the engine room are connected at the end, to the boilers, by 6-in. steam lines, with long-radius loops to take care of expansion and contraction. Fig. 8 gives a good idea of the piping arrangement for the entire boiler plant. Fig. 10 is a partial view of the boiler room. Smoke and gases pass through smoke flues to four 150-ft. chimneys, each with an internal diameter of 7 ft.

Economizers

At the rear of the boilers in No. 3 station are two economizers, Fig. 12, each containing 640 tubes. The flue gases leave the economizers at 300 deg., after heating the feed water from 120 deg. to 200 deg. F. The scrapers of each economizer are operated by a 7½-hp. 230-volt, direct-current motor. Two engine-driven fans supply the mechanical draft.

In case the feed pumps on the pumping engines fail to deliver sufficient boiler-feed water, auxiliary feed pumps in a pump room at the rear of the boiler can be used to supply this deficiency.

Coal and Ash

Fuel is delivered to the plants by either water or rail; if by water, the coal is unloaded at the wharf into coal cars and drawn by a small locomotive to the square building partly shown in Fig. 11, and shown in sections in Fig. 13. Rail shipments are hauled to the same building, where the fuel is dumped through the bottom of the cars into a track hopper, from which it is fed to the crushing rolls and conveyed by a pivoted bucket elevator to the top of the elevator house, and is then discharged onto a 425-ft. belt conveyor. The belt conveyor runs to both boiler rooms and discharges the coal into the coal bunkers above the boilers, of which there are two, having a total capacity of 3000 tons.

The ashpit of each boiler is divided into two sections, one for fine coal sifting through the stokers, the other for ash falling from the rear end of the stokers.

These pits have duplex gates at the bottom and the contents discharge into an end-dumping ash car running on a track in a tunnel under the boilers. All fuel is elevated from the tunnel level to the top of the track hopper, where it is dumped into the hopper and elevated to the coal bins to feed to the stoker again.

Ash is discharged into a similar car and is dumped into a skip car and elevated to the top of the ash bunker and discharged. Ashes are disposed of, either into a common coal car on the track in the elevator house and hauled away for filling-in purposes or is discharged into wagons through the spout shown at the side of the tower, Fig. 13.

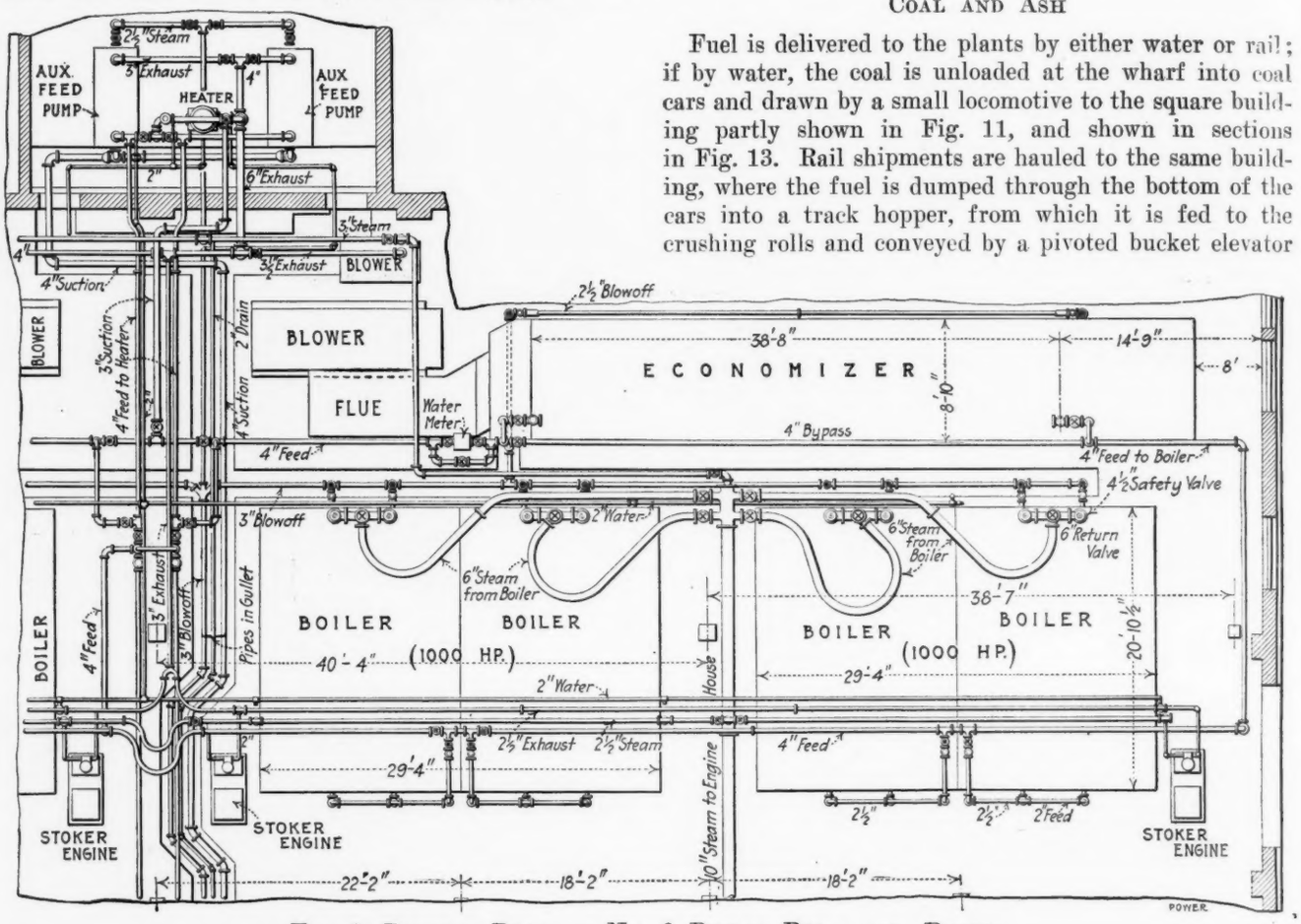


Fig. 8. Partial Plan of No. 3 Boiler Room and Piping

FIG. 9. STEAM HEADER IN BASEMENT; ALSO WATER MAIN

FIG. 11. WEIGHING A CAR OF COAL

FIG. 10. VIEW OF PART OF NO. 3 BOILER ROOM

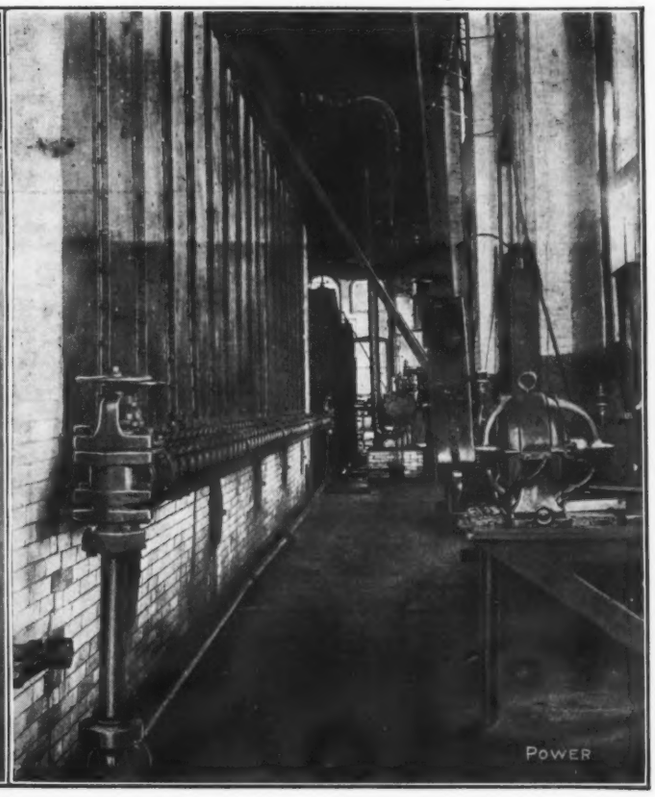


FIG. 12. REAR VIEW OF THE ECONOMIZERS

PRINCIPAL EQUIPMENT OF LARDNER'S POINT PUMPING PLANT

No.	Equipment	Kind	Size	Use	Operating Conditions	Maker
12	Pumps	Vertical, triple expansion	20,000,000 gal.	Pumping city water	Condensing, 175 lb. steam	Holly Mfg. Co.
14	Boilers	Water-tube	500 hp	Steam generators	Natural and forced draft, 125-lb. pressure	Edge Moor Iron Co.
2	Economizers	Green		Feed water	Motor driven scrapers	Green Fuel Economizer Co.
2	Chimneys	Custodis	150 ft. high, 7-in. internal dia	Boiler gases	Natural draft	Alphonse Custodis Chimney Con. Co.
2	Chimneys	Heinicke	150 ft. high, 7-in. internal dia	Boiler gases	Forced draft	H. R. Heinicke
14	Stokers	Wetzel	102 sq.ft. area	Boiler furnaces	Automatic	Wetzel Mechanical Stoker Co.
4	Pumps	Air, vertical	8x8x10"	Air for closing engine valve	105-lb. pressure	Westinghouse Air Brake Co.
2	Motors	Direct current	7½ hp	Economizer scrapers	1525 r.p.m., 230 volt	General Electric Co.
1	Conveyor	Belt	840 ft. long	Coal	Intermittent	Robins Conveying Belt Co.
1	Conveyor	Bucket		Ash	Intermittent	Jeffrey Mfg. Co.
3	Engines	Center crank	90 hp	Directly connected to generators	Non-condensing, 250 r.p.m.	Ridgway Dynamo & Engine Co.
3	Generators	Direct current	50 kw	Engine driven	250 r.p.m., 250 volts	

Miscellaneous

Electrical energy for operating the motors and for lighting is supplied by three 10x12-in. center-crank engines, each directly connected to a 50-kw., 250-volt, direct-current generator. These units are in the small building at the rear of No. 2 boiler house, shown at the right of Fig. 2. There is also one air compressor for blowing boiler tubes, etc.

The pumping plants of Philadelphia supply filtered water, freed of 99 per cent. of all bacteria, to approximately 326,000 homes and 1,550,000 people at a cost of less than one cent a day to each person. About 2000 men are employed by the water department and the aggregate daily capacity of all the city pumping plants is 709,000,000 gal.

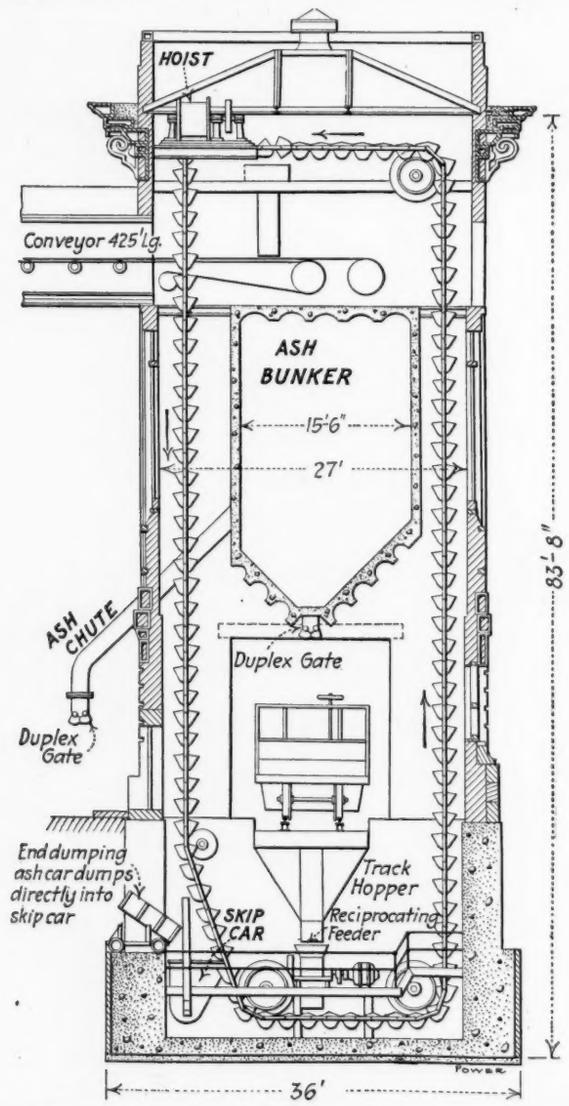


FIG. 13. SECTIONAL ELEVATION OF ASH- AND COAL-CONVEYOR HOUSE

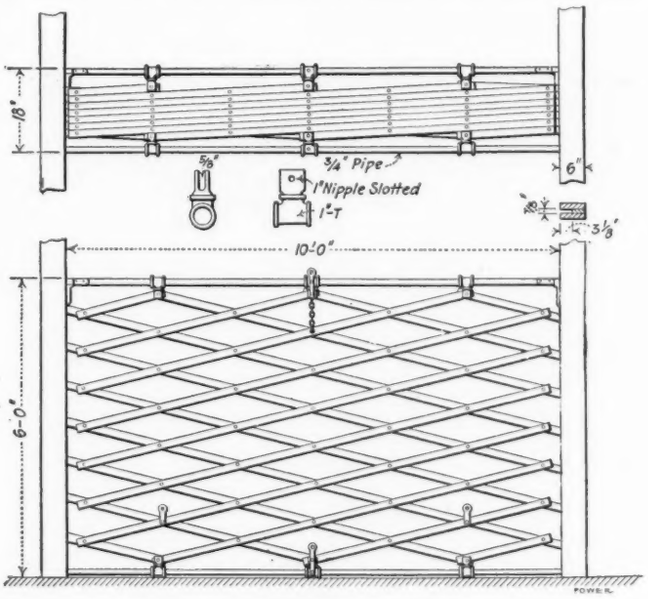
Collapsible Safety Elevator Gate

By A. G. Knight

The gate shown in the drawing was originally devised to comply with the Nebraska State Factory Laws, which require that freight elevators be provided with gates 6 ft. high and reaching to the floor instead of standing on legs as commonly arranged.

There has been so much comment from elevator inspectors, architects, building owners and others that the writer believes there are many who would like to use the gate as illustrated.

The main feature of the gate is that it closes in a space of 18 in. and can, therefore, be used where there is little headroom. Its top and bottom rails are made of ¾-in. black pipe flattened at the ends. The top rail has a small lug riveted near each end, the lugs resting on little iron blocks on the slides and holding the top rail at the proper height.



COLLAPSIBLE ELEVATOR GATE

The oak slats are 1½ in. wide by ⅝ in. thick, and are put together with $\frac{5}{16}$-in. carriage bolts. A washer on each bolt between the slats reduces the friction. The chain shown in the upper part of the gate is necessary in that

it keeps the gate from sagging down and getting out of the slides. These gates are quite large, have counterbalance weights attached to both top and bottom rails, and are opened by one or two ropes attached either to the bottom rail or to some part of the gate near the bottom. Different ways of opening the gate have been tried, but for a wide gate two ropes attached to the two eyes shown near the bottom of the gate are preferable.

The Blackstone Oil Engine

By J. A. Seager

Most satisfactory results have been obtained with a low-compression type of crude-oil engine, developed by Blackstone & Co., Ltd., Stamford, Eng., especially for using low-grade oils. The engine employs the four-stroke cycle and a compression of about 150 lb., the air for fuel injection being supplied at 450 lb.

With compression to only 150 lb., some additional means have to be provided to ignite the charge. This is effected by a dual spraying device consisting of a main jet delivering into the combustion chamber and an auxiliary jet delivering a small constant charge into a bulb-shaped ignition chamber heated at starting by a lamp and afterward kept hot by the heat of combustion. This ignition chamber communicates with the combustion chamber by a port so arranged that the flame impinges upon and ignites the main fuel sprayed into the combustion chamber. The oil is delivered from a tank to the spraying device by a governor-controlled pump and first reaches the auxiliary or igniter spray. All oil in excess of the quantity required for this overflows into the main spray. In this way the charge of oil is injected into the igniter at every cycle, keeping it hot, whether the engine is running light or loaded.

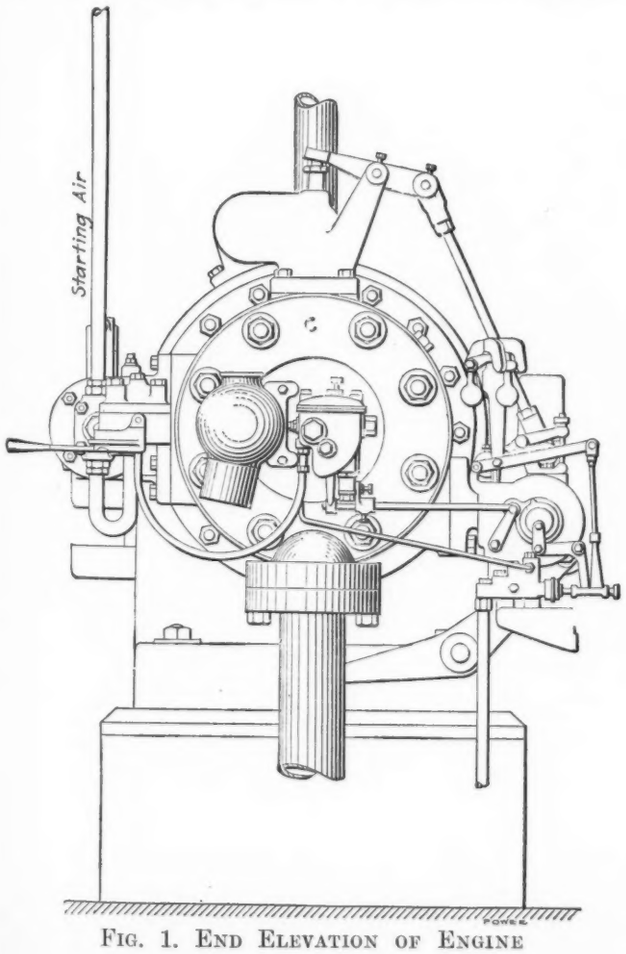


Fig. 1. End Elevation of Engine

Fig. 1 is a view of the cylinder end. The fuel is delivered to the spray chamber by a force pump, worked from the camshaft, the quantity pumped being determined by the action of the governor in raising or lowering into the pump ram. This ram travels home to a fixed point on the outward travel, and hence the length of the stroke home is dependent on the position of the wedge. If the load suddenly comes off the engine, the wedge is withdrawn, the stroke of the pump becomes nothing, and then gradually settles down to the fuel requirements.

The spray valve box and the igniter are shown in Fig. 2. In this spray box are fitted two needle valves, one,

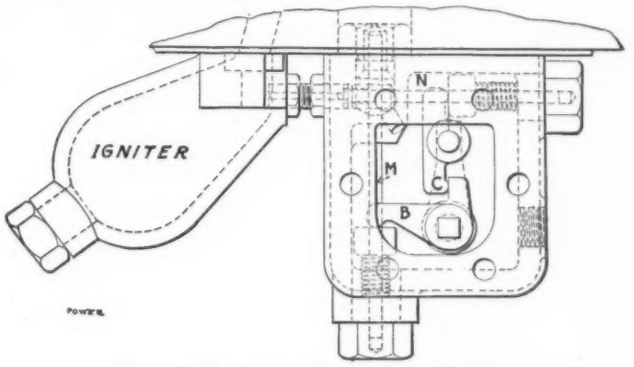


Fig. 2. Igniter and Fuel Valves

M, leading direct into the cylinder, the other, *N*, from the side of the spray chamber into the igniter which is a hollow bulb of cast iron kept red hot by the heat of the explosions. The opening of the main spray valve is effected by the lever *B* pressing against the inside of the spring collar, and the small tailpiece on the same lever acts upon the rocking lever *C*, causing it in turn to press at right angles upon the collar of the ignition spray valve, thus making them open together. The lift of these valves is slight, and is regulated by set-screws on the push rods. The ignition rocker lever is carried on an eccentric pin in the cover of the spray box and the correct opening of this valve is adjusted by turning the eccentric rod. This adjustment is the only one necessary for any class of fuel and must be made with the engine running.

The oil enters the spray box through an annular passage around the stem of the ignition valve, overflowing to the main spray chamber. Thus the quantity entering the igniter is fixed and independent of the load. The spray valve is so arranged that the oil cannot be blown in all at once but is gradually sprayed into the cylinder meeting the jet of flame issuing from the igniter. The

result is that the oil burns rather than explodes, the maximum pressure being only about 320 lb., although the mean effective pressure is said to be about 90 lb.

The valves are totally inclosed in a box in contrast to the usual arrangement of working the spraying valves through a packing gland. No mechanical atomizer with restricted ports is used, the fuel being simply blown into the cylinder by the air at 400 lb. pressure when the spray valve is opened. The compressor is of the two-stage, intercooled type with solid pistons of two diameters, the larger diameter compressing to 80 lb., and the smaller to 400 lb.

In a paper read before the Liverpool Engineering Society in March last, W. A. Simper gave some interesting figures of fuel consumption of various sizes of this engine. These are given in the following table:

FUEL CONSUMPTION AT DIFFERENT LOADS

1 Hp.	B.hp.	Full Load, Lb.	¾ Lb.	½ Lb.	¼ Load Lb.
19	15	0.57	0.61	0.69	0.93
25	20	0.52	0.55	0.625	0.84
37.50	30	0.5	0.533	0.6	0.8
56.25	45	0.48	0.52	0.575	0.76
75	60	0.47	0.5	0.56	0.75
113	90	0.46	0.49	0.55	0.73
150	120	0.45	0.48	0.54	0.72

The engines are constructed at present in single units with cylinders up to 20 in. in diameter and with two engines arranged in the twin type, powers up to 300 hp. at moderate speeds being developed. Owing to the low maximum pressure and the continued slow burning of the fuel, good speed regulation is claimed to be had without employing excessively heavy flywheels.

Solving the Cinder Problem at Waterside--IV

By Charles H. Bromley

SYNOPSIS—Revolving fans with large blades carrying perforated water pipes are placed in the flues and the base of the stack to take out the cinder in the gases. A cinder catcher on the top of the stack confines the solids in a hood from which they are pulled out by vacuum. Discovery of the successful cinder catcher. Evolving the successful apparatus.

It was realized, after several dry-cinder catchers were used, that apparatus wherein water was introduced into the path of the gases produced the best results.

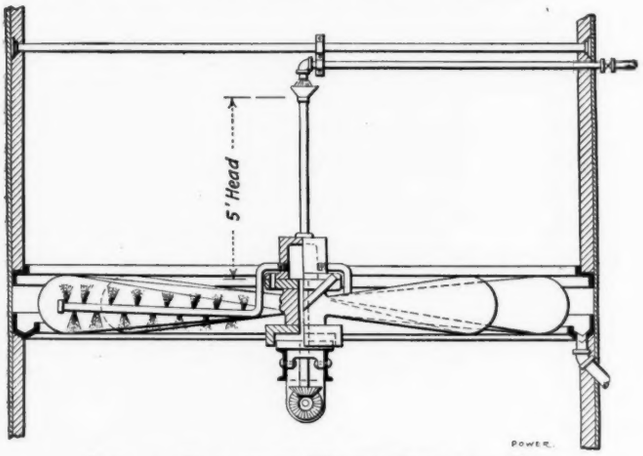


Fig. 14. Fan with Water Spray in Flue

An interesting apparatus using water, and one which would undoubtedly work successfully in some plants, consists essentially of large fans in the flues, each fan being driven by a motor outside the flue. The fan blades carry perforated water pipes to throw numerous sprays of water through the gases as the fan revolves, thus throwing down the cinder, which is gathered in a trough and washed out of the flue. Fig. 14 shows the details of one of the fans, its gear drive and its water connections. Another style, of fan having the water inlet on top and running on a roller or ball bearing was also used.

Troubles of All Water-Spray Cinder Catchers

One of the chief troubles with all water-spray cinder catchers in the flues and the stack is that the perforations in the water-pipe plug with cinder, scale, salt, etc., particularly if the holes are small to give a fine jet; if they are large the jet or spray is far less efficient. Where salt

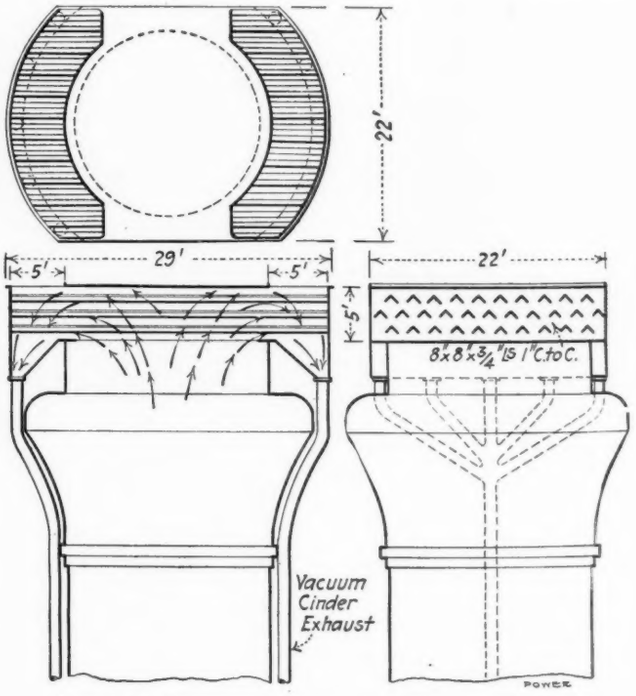


Fig. 15. Vacuum Hoods on Top of Stacks

water is used in such spraying apparatus, the equipment scales and becomes plugged with the salt which is deposited as the water evaporates, due to the heat of the flue gases. This deposit at the Waterside plants contains about 85 per cent. of salt, the remaining content being ash and carbon. The water is taken from the East River.

Vacuum Hoods for Smoke-Stacks

At Waterside No. 1 station, hoods were put on top of the smoke-stacks to catch the cinder; a hood consists of a shell perforated all around its circumference. Inside the shell were placed bars in lattice-work fashion to impede the progress of the cinder, which would then drop into the hopper-like sides of the hood and be sucked away by vacuum maintained by a pump in the plant. Fig. 15 shows the arrangement.

Another method tried was an electric cinder arrester, the intention being to precipitate the suspended particles by giving them an electric charge, so that they would be driven toward a series of collecting electrodes. After experimenting with this apparatus for some time, it was given up. The efficiency shown was not high enough, serious difficulties arose with the insulation under the high potentials employed, and the covering of cinder on the insulators dissipated the charge.

Evolving the Successful Cinder Catcher

The first experimental all-wet apparatus for cleaning the gases was a curved baffle-plate placed just beyond the boiler outlet, to deflect the gases in a downward direction, with a water tank below to catch the cinder. This

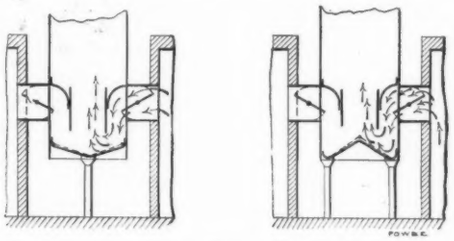


Fig. 16. The First Wet-Cinder Catcher; Two Schemes

simple apparatus having caught a large amount of the cinder, the next step was to increase the distance traveled by the gases in the downward direction and increase the velocity of the gases to forcibly project them upon the surface of the water, thus trapping a larger percentage of the cinder. This experimental apparatus gave good results. Fig. 16 shows two applications of this plan.

The gases were conducted downward through a four-sided, wedge-shaped duct tapering toward the outlet, three sides being vertical and the other inclined. The water level in the tank was maintained at 12 in. from the bottom of the duct.

While this outfit was being developed, another plan of wet cleaning was being tried out at Waterside No. 1. The lower-floor boilers at that station discharged their gases downward into a flue in the basement. An inclined baffle was placed in the flue, and a sheet of water was maintained flowing over the upper surface of the baffle, so that the gases would drive the suspended solids against and into the water, which, with the trapped cinder, ran out at the bottom of the flue. End and side sectional elevations of this catcher are shown in Fig. 17. A concrete mattress used in the bottom of the flue in Waterside No. 1 lasted only a few weeks, due to the action of the water, the acids and the heat.

The next plan was to combine the stationary baffle and water sheet of the last apparatus with the baffle of the first outfit, to increase the velocity of the gases. The results were so satisfying that an apparatus, similar in general but differing in important details, was made and installed in Waterside No. 2 station.

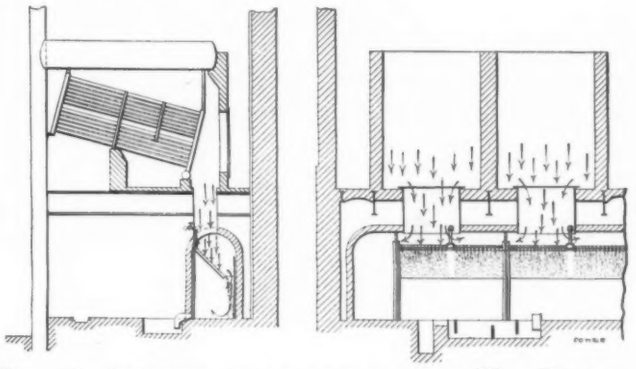


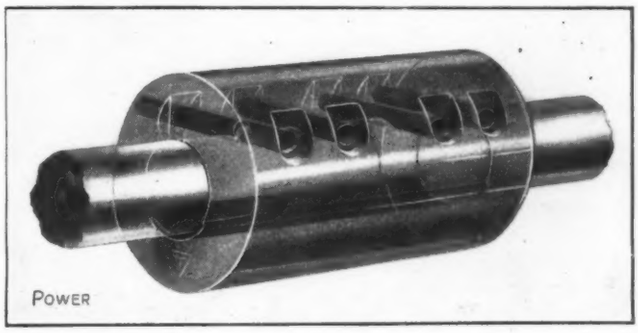
Fig. 17. Another Application of the Wet Process

This new and successful apparatus, its details and the trouble encountered in its operation, will be described in an early issue.

Safety Shaft Coupling

The illustration shows a safety self-keying shaft coupling, recently developed by the Thomas Coupling Co., Warren, Penn., and made in two sizes for shafts from $1\frac{3}{16}$ to $2\frac{15}{16}$ and 3 to 6 in., respectively.

It consists of a round iron or steel casting, through which a hole is bored lengthwise to accommodate the ends of the shafts to be coupled. Lengthwise through the bore a clearance space is milled which allows for two bearing spaces the length of the coupling. At the side of the coupling and transverse to the bore are the key holes, accurately laid out and drilled, entering a portion of the bore. In these small side holes cupped-end tool-steel pins are forced to a drive fit. These pins



Safety Shaft Coupling

are easily driven with an ordinary hammer, cutting away the portion of the shaft which extends above the bed of the pin, thus locking the shaft both ways and eliminating the necessity of keyseating the shafting. It will be noted that this type of coupling is devoid of projecting parts.

Largest Pelton Wheel in Switzerland—The Swiss hydraulic plant situated on the Lontsch River is using what is claimed to be the largest Pelton wheel in Europe, the wheel being of 15,000-hp. capacity. In this station there are six Pelton wheels of 6500 hp., so that this latest wheel brings the output of the Lontsch plant up to 54,000 hp. The plant is one of the largest in Switzerland.

Wreck of Corliss Engine

By Charles O. Wilkes

A 450-hp. Corliss engine at the Athens Brick Co., Athens, Ohio, wrecked itself recently, doing considerable damage to the building and a fine residence about 700 ft. distant.

The 16-ft. flywheel, having a 45-in. face and weighing about 10 tons, was completely demolished and thrown through a 12-in. wall, breaking a 10-in. steam-exhaust line, throwing it and many other obstacles in every direction. Other steam lines were broken, as was the safety valve on one of the boilers, allowing live steam to fill the boiler and engine rooms. Fortunately, no lives were lost though one man was trapped in the engine room at the time of the accident.

Photographs will tell more than words and still not fully describe the damage done. Fig. 1 shows a view through the engine room from the boiler room, taken through an opening in the 12-in. wall made by the bursting wheel. The 12-in. shaft is seen to be bent and the hub of the wheel still mounted and keyed in position. This hub weighs nearly a ton. The cap on the main bearing has been lifted and the engine bed beneath the main bearing broken.

In the distance is the large driven pulley which was not damaged despite the flying missiles. At the immediate right can be seen an opening in the wall made by the leather belt when it broke, heavily striking against the brick, crowding the wall out and breaking back about 4 ft. into the wall at the immediate right.

Fig. 2 shows only a small part of the distortion of the crank and connecting-rod. Only one more revolution would have been sufficient to completely wreck the cylinder, which was uninjured, so far as could be seen. This and some parts of the valve-gear were all that were worth saving.

Fig. 3 shows the engine room on the opposite side from that shown in Fig. 1. It shows also the opening in the 12-in. wall into the boiler room, indicating the damage done to the boiler setting and to the roof of the building. In this view one of the spokes of the flywheel is being removed. Two of them were found in the boiler room in a small alleyway where the fireman had started through to the engine room when it became evident that he could not prevent an accident. Seeing his danger and knowing he could not reach the engine in time, he turned and had just made his escape when the accident occurred.

A man employed to wheel coal into the boiler room was emptying a wheelbarrow when the fireman (who fell headlong into the coal pile) scrambled to his feet and shouted, "Look out!" He was greeted with an unconcerned "Huh?" The fireman had just found shelter

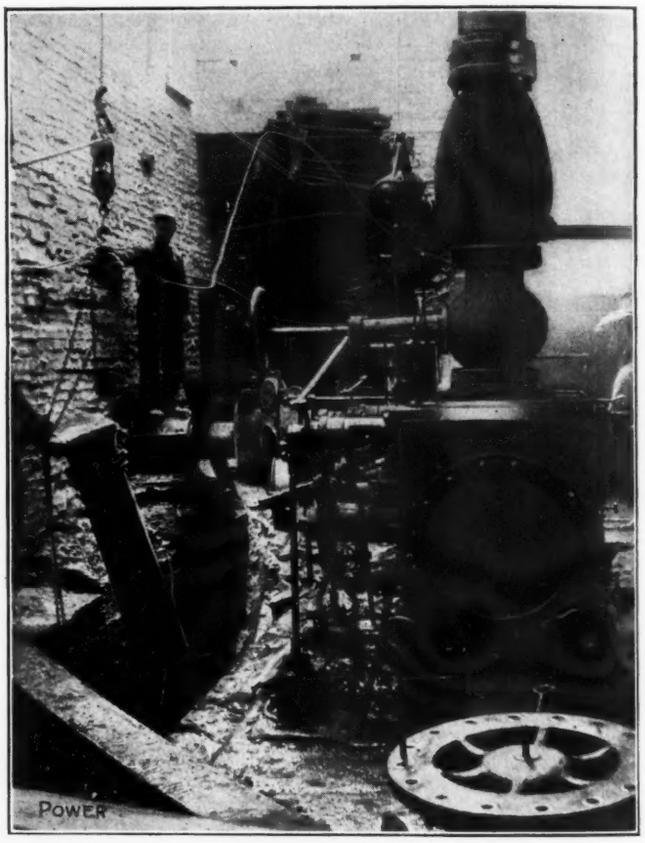


Fig. 3. Damaged Boiler Setting in Rear

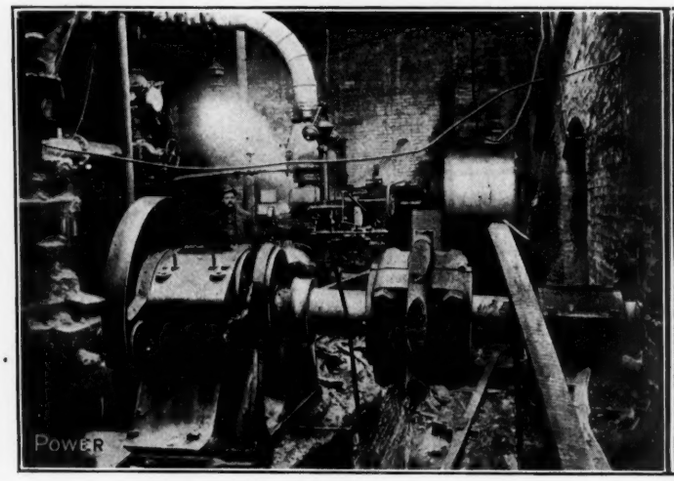


Fig. 1. General View of Engine Room

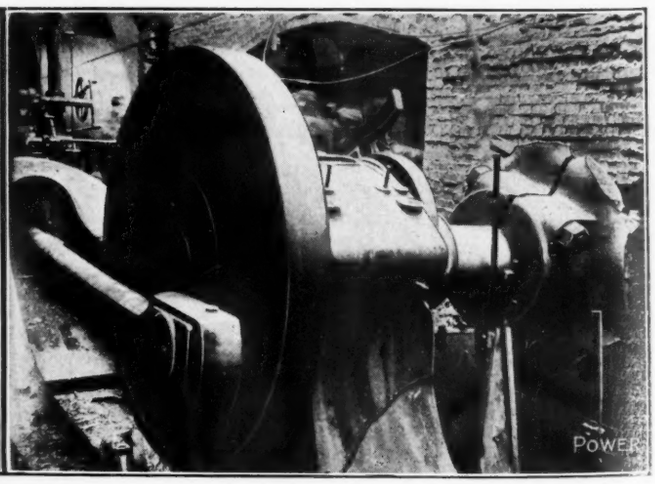


Fig. 2. Cracked Pillow Block and Bent Rod

beneath a carload of coal when iron, bricks and everything movable came showering down. He came out only to find his fellow employee unloading the wheelbarrow.

The real cause of the accident is unknown, although it is thought to have been due to a slipping governor belt that allowed the engine to exceed the critical speed. If the belt had broken it would have allowed the idler wheel-lever to drop and so stop the engine.

Terry "Return-Flow" Turbine

SYNOPSIS—A new Terry product of the combined velocity- and pressure-stage type designed to run condensing. The low-pressure nozzles are mounted in detachable segments on the diaphragms. The cylindrical bearing housings and suspended casing are features of the design. Forced-feed lubrication is provided.

The "Return-Flow" Feature

The most common of Terry turbines familiar to engineers is of the velocity-stage type using one rotor and redirecting buckets, and run noncondensing. The latest Terry machine, Fig. 1, has been designed to operate condensing and, for the present, at least, will be made in sizes up to 500 kw. It is a combination multivelocity- and pressure-stage machine, using one wheel and redirecting buckets for the high-pressure end, and a series of multipressure-stage elements for the low-pressure end, as in Fig. 3

As indicated by the arrows in the sectional view, Fig. 3, the steam, after being used and expanded to slightly above atmospheric pressure in the velocity-stage chamber, is conducted to the pressure-stage lower-pressure end which is reversed; that is, the flow of steam through it is in a direction opposite to that at which the initial pressure steam entered. It is this feature which gives the turbine its name of "return flow."

Steam-Sealed Shaft-Glands

This design admits of constructing a unit that is not only compact but one in which the glands are sealed against air leakage without the use of water seals or a pumping equipment. The external shaft-glands are sealed against leakage by steam at a pressure slightly above atmospheric, as in Fig. 3, the tinted area of which indicates the part subjected to vacuum. It is sometimes difficult to tell if increased air leakage into the vacuum system and consequent reduction in vacuum is due to leaks at the shaft-glands or elsewhere, but with this design the leakage must be looked for elsewhere.

Nozzles Mounted on Detachable Segments

The nozzles for the low-pressure end are of drawn material with hardened surfaces, and are mounted on annular rings made in segments, any of which may be removed without disturbing the rest. This is of decided advantage, because it is possible to inspect or remove any blades without cutting or disturbing those adjacent. The blades are held by riveted, removable key-pieces and are shrouded.

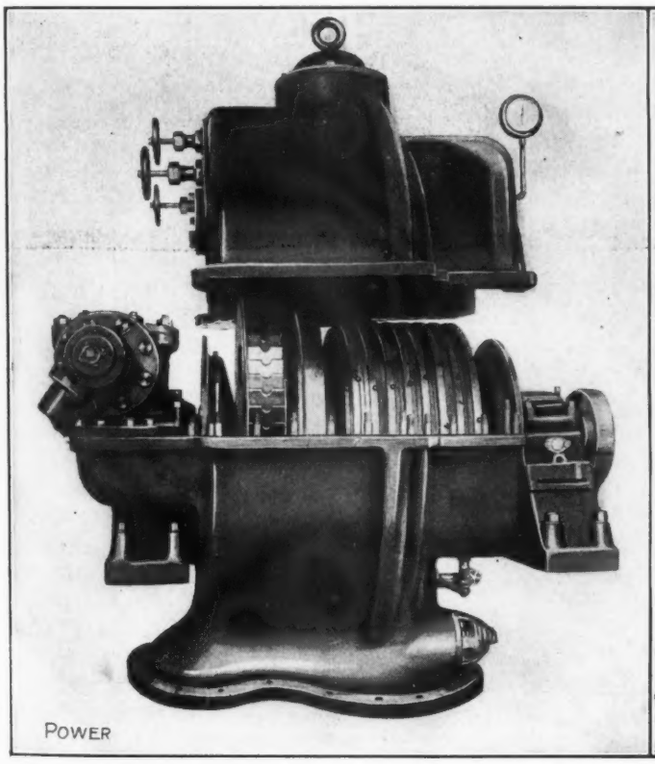


Fig. 1. The "Return-Flow" Turbine

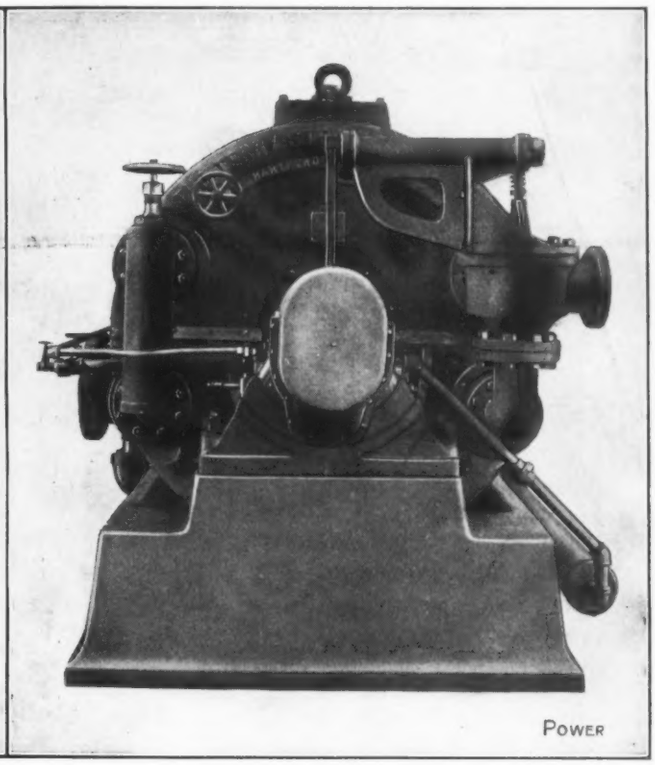


Fig. 2. Showing Features of Design

The rotor rests on pedestal bearings supported directly from the baseplate. In Fig. 3, note that the seats for the bearing housings are cylindrical, being bored at

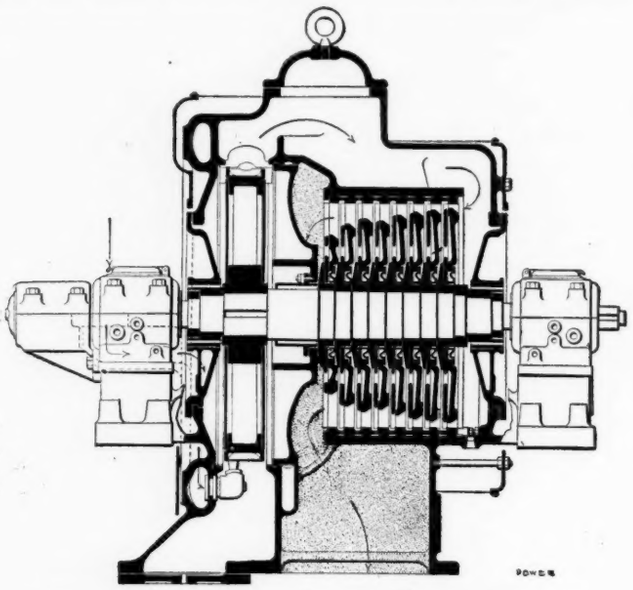


FIG. 3. SECTION OF "RETURN-FLOW" TURBINE

the same setting with the casing, which, as shown, is not supported by feet resting on the baseplate, but is suspended from the bearing. This feature is commendable, as the operator need experience no difficulty in lining up the machine if he should dismantle it, for when the bearing housings are pulled down on their seat the rotor must come concentric with the casing. The flow of steam through the turbine tends to equalize the temperatures of the ends and to avoid distortion due to expansion and contraction. To further assist in this by reducing the conduction of heat from the pedestal blocks to the bearings, the blocks are hollow, with a hole in each for air circulation, and the cylindrical seats consist of two strips with an air pocket between them.

The governor, of the direct type, operates the double-seated regulating valve through levers and a ball-bearing rocker shaft. For alternating-current units either a hand- or a remote-controlled synchronizing device is furnished. The regulating valve is, of course, of the double-seated balanced type and is provided with a heavy cylindrical screen which completely surrounds the valve seats and allows for a large annular space between the valve body and the screen.

LUBRICATION

The bearings are water-jacketed and supplied with forced-feed lubrication by a screw-type oil pump in the baseplate between the turbine and the driven unit. Ring-oiling lubrication is also provided to be used when emergencies demand.

Calculating Power in Alternating-Current Circuits--I

BY NORMAN G. MEADE

SYNOPSIS—A simple explanation of the terms power factor, wattless current, self induction and capacity; also how they are determined.

Engineers and electricians having charge of circuits with induction-motor loads realize the difficulty of keeping up the power factor of the system. No matter how much care is taken to install motors whose rated capacity is close to the power requirements, the power factor is still regarded by many as a "skeleton in the power-house closet."

POWER FACTOR

In direct-current circuits the product of the simultaneous readings of the voltmeter and ammeter give the watts delivered. With alternating current this product gives the apparent power only, which may be greater than the real watts as indicated by a wattmeter connected to the circuit. The ratio of the wattmeter reading to the product of the voltmeter and ammeter readings is called the power factor. This is never greater than unity, and is usually expressed in percentage. If the true power is expressed in kilowatts and the apparent power as the product of kilovolts (1000 volts) and amperes, then the following relations will be found to hold true:

$$power\ factor = \frac{real\ watts}{apparent\ watts} = \frac{kilowatts}{kilovolt\text{-}amperes}$$

The power factor may also be considered as equal to the cosine of the angle of lag or lead of the current behind or ahead of the electromotive force. In Fig. 1, OE represents the electromotive force and OC the current, 45 deg. behind the electromotive force. The relation of electromotive force and current is also illustrated by the sine curves representing one complete cycle. It will be

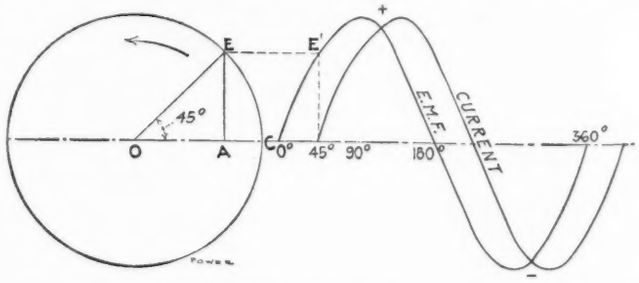


FIG. 1. GRAPHICAL REPRESENTATION OF CURRENT AND VOLTAGE VALUES

seen that the electromotive force has reached a value corresponding to E' before the current starts from O, 45 deg. behind it.

The vertical line AE is called the sine of the angle, and the horizontal distance OA is the cosine. From tables of natural trigonometrical functions the cosine of 45 deg. is found to be 0.707; hence the power factor is 0.707, or approximately 0.71. When the angle of lead

or lag is 90 deg., the cosine of the angle is zero and the true watts expended are zero; that is, the current is said to be wattless. When the angle becomes greater than 90 deg., the cosine becomes negative, thus showing that the machine, if a motor, is delivering energy to the circuit. From the foregoing, it becomes evident that it is possible to have large alternating currents flowing under high electromotive forces and at the same time have but little energy expended.

For a given amount of power transmitted, the current will be smaller if the power factor is high than if low.

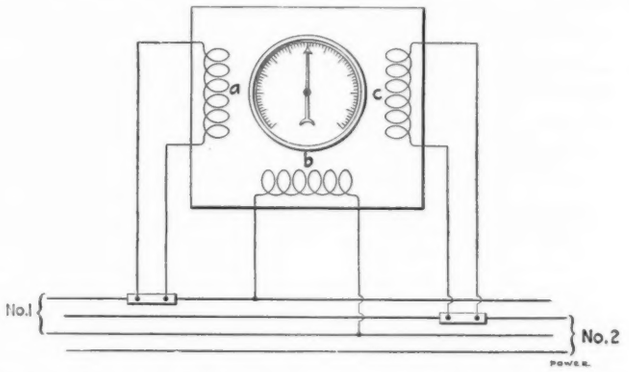


FIG. 2. REPRESENTING CONNECTIONS OF POWER-FACTOR METER

Let it be desired to transmit 100 kw. over a line by means of alternating current, the load consisting principally of motors, and assume that the current lags behind the electromotive force by an angle of 25 deg. The cosine of an angle of 25 deg. equals 0.90; therefore the power factor will be 90 per cent., and

$$true\ watts = volts \times amperes \times 0.90$$

Assume the line pressure to be 1000 volts. The power delivered is 100 kw., or 100,000 watts; then the current equals

$$100{,}000 \div (1000 \times 0.90) = 111.1\ amp.$$

instead of 100 amp. with unity power factor. This illustrates the necessity of maintaining as high a power factor as possible.

WATTLESS AND POWER COMPONENTS

Current in an alternating circuit to which an inductive load is connected can be considered, as resolved into two components, one at right angles to the electromotive force and one in phase with it. The component at right angles is known as the wattless component, and that in phase with the electromotive force as the power component. The greater the angle of lag or lead of the current the larger will be the wattless component and the smaller the part which is really expending power in the circuit.

Although wattless currents do not represent any power wasted, they are objectionable, because they load up the lines and the generators, and limit the current-carrying capacity. For example, assume a generator supplying 30 amp. to a system with a low power factor. The actual power delivered would be small and the prime mover driving the generator would be lightly loaded, but the current of 30 amp. is circulating through the lines and the armature of the generator, loading the lines and heating up the machine. As the current output of the armature is largely limited by heating, the useful current which the generator could deliver is greatly reduced by the wattless component.

MEASUREMENT OF POWER FACTOR

The power factor is measured by a phase-angle indicator or power-factor meter; the connections for a two-phase instrument of this type are shown diagrammatically in Fig. 2. The current in the series coils *a* and *c* produce a rotating field, and that in the shunt coil *b* produces an oscillating field. The shunt coil is free to rotate and will take up a position in which its oscillating field will be in time phase with the resultant rotating field in that plane. If the electromotive force is in phase with the current, the coil, to which a pointer is attached, will assume the position shown by the pointer.

Power-factor meters are always installed with series transformers in the series circuits, the current in the coils being limited to from 3 to 5 amp. Frequency has no effect upon the accuracy of the readings, but unbalancing of the phases may cause serious errors.

The connections can be checked by disconnecting the voltage coil and noting the direction of rotation of the pointer. If the series coils are not properly connected,

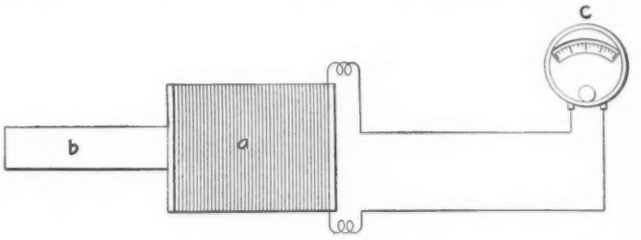


FIG 3

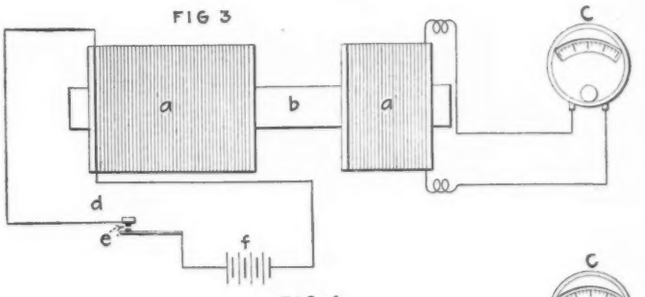


FIG. 4

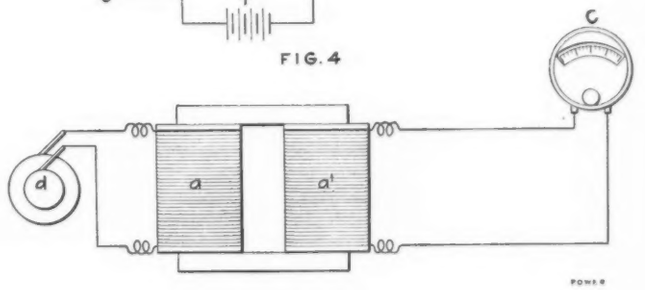


FIG. 5

FIGS. 3, 4 AND 5. ILLUSTRATING SELF-INDUCTION

the pointer will either rotate in the lag direction or not at all. The mechanism is mounted in a case provided with a dial with the zero mark at the center; lagging and leading currents are scaled off right and left from zero, the divisions representing the percentage of power factor.

SELF-INDUCTION AND CAPACITY

Power factor has been defined and its effects illustrated, now the causes for leading and lagging currents will be considered. A load consisting entirely of in-

candescent lamps is practically noninductive, but where arc lamps and induction motors form the load, or part of it, self-induction is always present and a lagging current results.

Whenever the number of magnetic lines of force threading through a circuit is caused to change in any way an electromotive force is set up in the circuit, and the average electromotive force so generated depends upon the average number of lines of force changed per second. For illustration, let *a*, Fig. 3, represent a coil of wire or solenoid, *b* a permanent magnet and *c* a low-reading voltmeter or a galvanometer. Lines of force may be made to thread through the coil by inserting the permanent magnet in its center opening and then moving it backward and forward so as to cause the number of lines passing through the coil to vary. This will establish an electromotive force as indicated by the voltmeter.

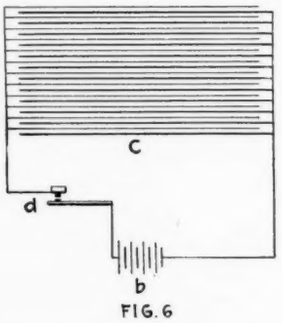


FIG. 6

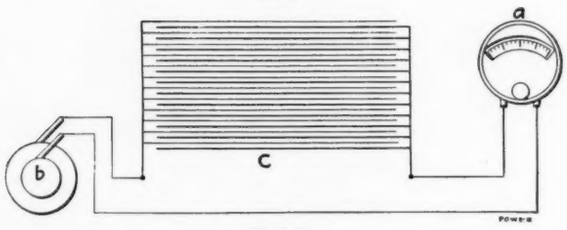


FIG. 7

FIGS. 6 AND 7. ILLUSTRATING CAPACITY

The electromotive force so generated will be alternating.

Now consider Fig. 4, where *a* and *a'* are coils wound on a core of soft iron *b*; *c* is a voltmeter, *d* a key with contacts *e* and batteries *f*. When the key is closed the current flows in coil *a*, magnetizing the core *b*. The lines of force rise from zero to maximum and cut the turns of wire in coil *a'*, causing an induced current to flow for a fraction of a second, and the voltmeter *c* will show a deflection. Upon opening the key the current in *a* will cease and the lines of force set up in the core will fall from maximum to zero, during which time current will again be induced in *a'*, but in a direction opposite to that when the key was closed.

Finally consider two coils, *a* and *a'*, as in Fig. 5, the former connected to a source of alternating current. An alternating current will be established in *a'* and the voltmeter *c* will show a continuous indication.

Lines of force may also be made to thread a coil by sending a current through the coil itself. If a current be sent through a coil, lines of force will be set up about it, the path being through the core and back through the surrounding air to the opposite end of the core. So long as the current remains steady, these lines will not change, and the current will flow through the coil just as though it were an ordinary resistance; that is, the current would follow Ohm's law. If there is a variation in the current, however, there will also be a variation in the number of lines of force threading the coil; therefore there will be an electromotive force set up in the coil. This electromotive force of self-induction tends to oppose any change in the current. In direct-current circuits there are no self-induction effects as the current is steady and no induced electromotive forces can be set up.

Circuits containing resistance can be made which have practically no self-induction and are known as noninductive resistances; such circuits are governed by Ohm's law and incandescent lamps or water resistances are good examples.

So far, only lagging current has been considered, but circuits containing capacity in excess of self-induction cause the current to lead the electromotive force. The property which most circuits possess of holding charges of electricity is known as electrostatic capacity. In underground cables the capacity effect is important as the copper conductor and the lead sheathing act similar to a condenser.

If it is desired to introduce capacity in a circuit, a condenser is generally employed. A condenser consists of a number of sheets of tinfoil separated by oil paper, mica or other suitable insulating material. Every alternate strip is connected to a common conductor and the remaining sheets to another conductor, as in Figs. 6 and 7, there being no electrical connection between the two sides of the circuit. If a battery *b* is placed in circuit with the condenser *c*, by means of the key *d*, current will flow into the condenser for a fraction of a second and then cease when the condenser is said to be charged. If, then, the battery is disconnected and the condenser terminals connected, the condenser will discharge.

In Fig. 7, the condenser *c* is connected in circuit with an alternating-current generator and an ammeter *a*. When the generator is in operation the ammeter will show a continuous reading, although there is no electrical connection to establish a circuit. If direct current were applied the ammeter would show no reading.

The effect of capacity in a circuit is exactly opposite that of self-induction and tends to give a leading current. When capacity and self-induction are both present in a circuit, one tends to neutralize the other.

The unit of capacity of a condenser is called the farad and represents a current of one ampere flowing for one second, which raises the pressure across the condenser terminals to one volt. The farad is too large a unit for convenient use and instead of it the practical unit, the microfarad, has been adopted; this equals one one-millionth of a farad.

Unique Emergency Power Plant

When a manufacturing plant has to replace an inadequate battery of boilers with one of greater capacity, it is not a simple matter to make the change without interrupting operation. This condition confronted Schaum & Uhlinger, Inc., Philadelphia, Penn., makers of textile machinery and centrifugal hydro-extractors. Buying current from the local company was too expensive, so the idea of utilizing locomotives was considered. The location of the plant, on the Pennsylvania main line, made feasible the storage of locomotives on a freight siding.

It remained a problem, however, to get locomotives

of the proper capacity; in these days of heavy railroading small engines are rather difficult to obtain.

Two "American" type locomotives were finally obtained from the Pennsylvania at a reasonable rental. While these were doing service, the old battery of two boilers was replaced with a 462-hp. Heine boiler, fired by a Taylor stoker. The furnace has an extension grate, giving enough area to insure absolute combustion without necessitating a brick arch. An American blower is used for forced drafts.

The process of substitution was simple but effective. The two old locomotives, whose connecting-rods and valve-gears had long been disconnected, were hauled to a convenient point on the siding after the tenders had been uncoupled, the throttle valves were closed, and a connection piped from the auxiliary domes over the fireboxes to the main steam lines in the plant. Their positions, back to back, with an elevated platform erected between them, allowed sufficient space for two firemen and a good coal supply that could be replenished without interrupting the service.

This means of steam supply is hardly economical enough to warrant its retention for a protracted period, since the amount of coal consumed per horsepower-hour is far greater than the average manufacturing plant can afford, but there is no question that money for the excess coal consumption, in addition to the moderate rental and the labor, is well spent when a continuous steam supply is assured that keeps the plant in operation during the installation of the new boilers, and whose connection with the main steam supply can be made in a short time at night without stopping operations.

Use of the Pitot Tube*

Pressure readings of 1 in. or less should be taken on an Ellison differential draft gage, graduated to at least hundredths of an inch, and calibrated by a hook gage; over 1 in., either with an Ellison gage or with a U-tube graduated to at least tenths of an inch. Great care should be exercised to have perfectly tight connections, especially on the static side. A slight loss of pressure here will cause a correspondingly high velocity pressure reading, and therefore indicate too great a velocity.

The reading should be taken at a cross-section where the pipe is straight and the flow undisturbed, preferably at least 10 diameters from the fan outlet, from an elbow, or from a change in cross-section in the duct. This condition is difficult of attainment in many installations and where it cannot be had the average of the maximum practicable number of readings at the point farthest away from the outlet or obstruction should be taken. Take the readings over a plane at right angles to, with the tube pointed in a direction parallel to, the direction of the air flow.

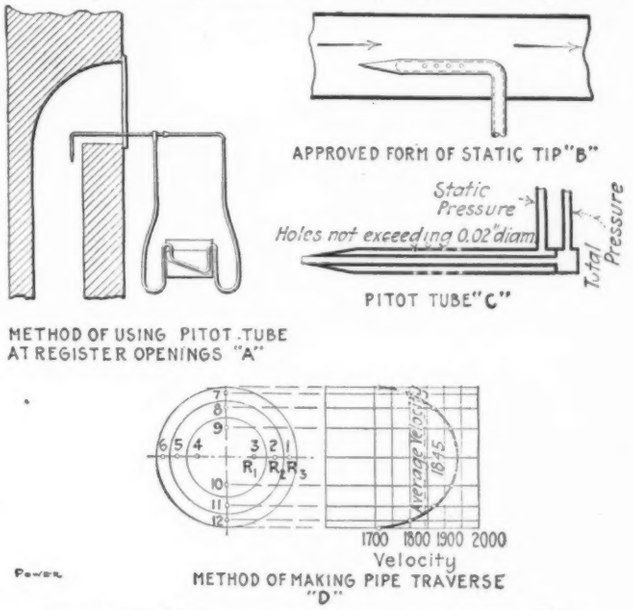
Pressure readings cannot be made over the face of an outlet with a pitot tube as is done with anemometer, but by inserting the tube in the pipe at the edge of the outlet with the tip of the tube pointed against the air flow, under the same conditions as in diagram *A*; a traverse of the pipe can be made at a point just before it reaches the outlet.

The most difficult reading to take accurately in a current of air is the static pressure. The approved form of static tip diagram *B*, is that recommended for fan-testing work. There should be eight or more clean holes 0.02 in. in diameter, an equal number on each side of a ¼-in. tube $\frac{1}{32}$ in. thick.

The most approved form of pitot tube combines the foregoing static tip with an impact tube, diagram *C*, by means of which total, static or velocity pressure may be read.

In making a traverse of a rectangular duct the cross-sectional area may be divided into a number of smaller rectangles and a reading taken in the center of each small rectangle.

A round pipe should be divided into at least three concentric zones of equal area per foot in diameter, and four readings taken on a circle drawn through the center of area of each zone or ring; that is, readings should be taken across the horizontal and vertical axis of the pipe, diagram *D*. Table 1 gives the distances from the center of the pipe to the points of reading, expressed in percentage of the pipe diameter. To get exact results a small pipe should be divided into relatively more zones than a pipe of larger diameter as the ratio of frictional surface to cross-sectional area is greater; hence the more static pressure in proportion to the impact pressure, which correspondingly reduces the velocity pressure.



STANDARD METHODS OF USING THE PITOT TUBE

TABLE I. PIPE TRAVERSE FOR PITOT TUBE READINGS

Distance from Center of Pipe to Point of Reading in Per Cent. of Pipe Diameter

No. of Equal Areas in Traverse	No. of Readings	1st R_1	2nd R_2	3rd R_3	4th R_4	5th R_5	6th R_6	7th R_7	8th R_8
3	12	20.4	35.3	45.5					
4	16	17.7	30.5	39.4	46.6				
5	20	15.5	27.2	35.3	41.7	47.4			
6	24	14.5	25.0	32.3	38.2	43.3	47.9		
7	28	13.4	23.1	29.9	35.3	40.1	44.3	48.2	
8	32	12.5	21.6	28.0	33.2	37.6	41.5	45.1	48.4

*From report of committee, J. I. Lyle, chairman, at annual meeting of the American Society of Heating and Ventilating Engineers.

The corresponding velocities for each of these readings should be determined and an average found of all of these velocities to compute the air quantity. Inasmuch as the velocity varies as the square root of the pressure, accurate results cannot be obtained by averaging the pressure readings and taking the corresponding velocity as the average.

The velocity may be determined from the velocity pressure by use of the formula

$$v = 1096.5 \sqrt{\frac{p}{w}}$$

where

v = Velocity in feet per minute;
p = Pressure in inches of water;
w = Weight of air in pounds per cubic foot under the existing conditions of temperature, barometer and humidity.

With dry air at 70 deg. and 29.92 in. barometer

$$w = 0.0749$$

whence the formula becomes

$$v = 4005 \sqrt{p}$$

With saturated air at 70 deg. and 29.92 in. barometer

$$w = 0.0735$$

and

$$v = 4046 \sqrt{p}$$

Where only approximate results are desired, for circular pipe, multiply the velocity pressure taken at the center of the pipe by 0.81 or the velocity by 0.91.

For rectangular pipe, no definite factor can be given even approximately correct which will cover the varying proportions of width to height of the cross-sectional area.

Table 2 gives corresponding velocities for various velocity pressures of dry air.

The committee recommended the pitot tube as a simple and convenient instrument for the measurement of air or gases, which, when used with the proper care and accuracy of reading, gives results with an error of less than 1½ per cent., with velocity pressures ranging from 0.1 in. upward.

TABLE 2. CORRESPONDING VELOCITY FOR DRY AIR AT VARIOUS PRESSURES AND TEMPERATURES

Pressure		Temperatures, Deg. F.									
In.	Oz.	50	60	70	80	100	150	200	300	500	550
0.1	0.0577	1242	1255	1266	1278	1300	1358	1413	1516	1704	1830
0.2	0.1154	1757	1776	1791	1808	1841	1921	2000	2145	2411	2590
0.25	0.1443	1965	1986	2003	2022	2059	2149	2235	2399	2696	2895
0.3	0.1730	2151	2175	2193	2214	2254	2352	2447	2626	2952	3175
0.4	0.2308	2485	2512	2533	2557	2603	2717	2827	3033	3409	3665
0.5	0.2884	2778	2808	2832	2859	2911	3038	3160	3391	3812	4095
0.6	0.3460	3043	3076	3102	3131	3188	3327	3462	3715	4175	4490
0.7	0.4037	3287	3323	3351	3383	3445	3595	3740	4013	4510	4850
0.75	0.4326	3402	3439	3468	3501	3565	3720	3870	4153	4668	5020
0.8	0.4614	3524	3552	3582	3616	3682	3843	3997	4290	4821	5185
0.9	0.5190	3728	3768	3800	3836	3906	4076	4241	4550	5114	5500
1.0	0.5768	3929	3971	4005	4043	4117	4296	4470	4796	5390	5795
1.25	0.7209	4393	4440	4478	4520	4602	4804	4997	5362	6027	6470
1.50	0.8650	4812	4864	4905	4952	5042	5262	5474	5874	6602	7100
1.75	1.0092	5197	5254	5298	5348	5446	5683	5912	6344	7131	7655
2.00	1.1535	5556	5616	5664	5718	5822	6076	6320	6783	7624	8195
2.25	1.2975	5892	5956	6007	6064	6174	6443	6704	7193	8085	8690
2.50	1.4418	6211	6278	6332	6392	6508	6792	7066	7582	8523	9150
2.75	1.5860	6514	6585	6641	6704	6827	7124	7412	7952	8938	9600
3.00	1.7300	6807	6879	6937	7003	7130	7440	7742	8307	9336	10000
4.00	2.3070	7857	7942	8010	8086	8233	8592	8940	9581	10780	11580
5.00	2.8840	8772	8867	8943	9027	9192	9593	9980	10710	12037	12900
6.00	3.4600	9623	9728	9810	9903	10083	10523	10950	11750	13203	14180

T. Hunter, Hoisting Engineer

By Warren O. Rogers

SYNOPSIS—Some facts about boiler operation are discussed by the chief fireman of a large power station. An evening spent in his boiler room showed a well organized, efficient crew, contrasting in every way with the men and the methods employed in most mine boiler plants.

After leaving Hunter on the evening of our last conversation, I strolled out to the large power house of the street-railway company to see what boiler-room practice was in vogue there. The head fireman was right on the job and every move of the men in the watch was known to him. After a little jockeying for position, so to speak, we had a sociable and interesting talk.

"How is it," I asked, sidestepping a hurrying fireman, "that your men are all attending strictly to business instead of swapping stories? How do you manage it?"

"Simplest thing in the world. In the first place, they are well paid, which counts for a whole lot. An underpaid fireman, like any other man, won't do any more than he has to in order to hold his job. My men know that if they do not do good work, there are those who will, and they also know that I have a waiting list of good men, any one of whom would be mighty glad of the chance to step into this plant."

"Of course, having mechanical stokers makes some difference in the way you handle your boilers, much different from what I have seen at most mine boiler plants, but you must have your troubles for all that."

"No doubt about it," was the reply, "but we don't tell of them. The management of a boiler plant like this," and he waved his hand toward the row of powerful water-tube boilers, Fig. 1, "is much different from what will be found at a colliery. Here we make a business of making steam to use in the form of electrical energy to transport the public. At a mine the power plant is considered a necessary evil that must be endured.

"I know all about it, for I have worked in them. If I were to take charge of such a plant today, I would insist on the firemen exercising as much care and intelligence in firing as I do in this plant. I would not allow such conditions as exist in this boiler room," and he handed me a photograph, as shown in Fig. 2.

The peak load for the night was over by this time, and we had gone into the chief fireman's office where we could

talk uninterruptedly and burn up a few local-brand of cigars. After we were comfortably seated, I said: "Now, if you were in charge of a hand-firing mine plant, how would you work the men to obtain the best results?"

"I would insist upon the men following a few simple rules, such as experience has determined to be the best. First of all, the men would be required to fire evenly and at regular intervals, firing approximately the same amount of coal at each charge. If the fires are kept in

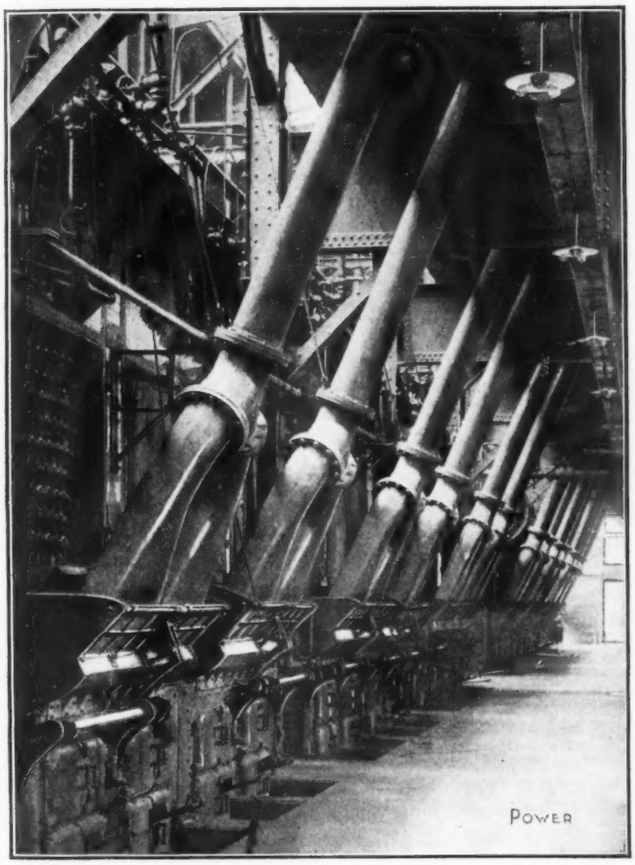


FIG. 1. A ROW OF POWERFUL BOILERS

proper condition, not more than five shovelfuls of coal will be required at each firing. This kind of firing would force the men to put the green coal on the thin places only.

"Where most firemen intentionally waste fuel is to pile the coal all over the fire, regardless of its need. The idea is to get a resting spell between firings, economy be blown!

"Another thing is to keep the fires clean and bright. This cannot be done if the shaking grates are not operated. At certain periods fires should be thoroughly cleaned the same as if stationary grates were used. Furthermore, a fire cannot be kept even if huge chunks of coal are thrown into the furnace just because the men won't take the trouble to break them up; they would have to do so, if I were in charge."

"Would such firemen do their work properly if they received a suitable wage instead of a boy's pay?" I asked, at the same time noting the wide-awake, alert actions of the men out in the boiler room.

"Probably some of them would, and then there are a few who have become so used to the haphazard method of stoking that it would be most difficult to get them to adopt new methods without a struggle, which wouldn't be worth while.

"It is difficult to make them understand that the draft and air supply must be regulated to suit the working conditions and so if the demand for steam decreases, the safety valves blow before much, if any, attention is given to the draft. Then the ashpit doors are kicked shut, if the accumulation of coal on the floor will permit. This accomplished, they sit down surrounded by dust and dirt until the steam pressure has dropped, when the ashpit doors are kicked open, and the fires are vigorously barred to quickly get the boiler steaming again. A fire should never be barred unless it is absolutely necessary.

"If such firemen would use their heads they would watch the condition of the fires and the steam pressure, because the latter is dependent upon the former. If the steam pressure rises or falls it is because a change of temperature has occurred in the furnace. The steam should be maintained at a constant pressure and the feed water at a uniform level, not out of sight at one time and above the third gage at others."

"I have noticed," said I, stroking the back of the cat that was industriously rubbing back and forth against the leg of my chair, "that in many boiler plants the settings are badly cracked and the furnace doors are cracked and warped. In some cases, the front-tube doors have been

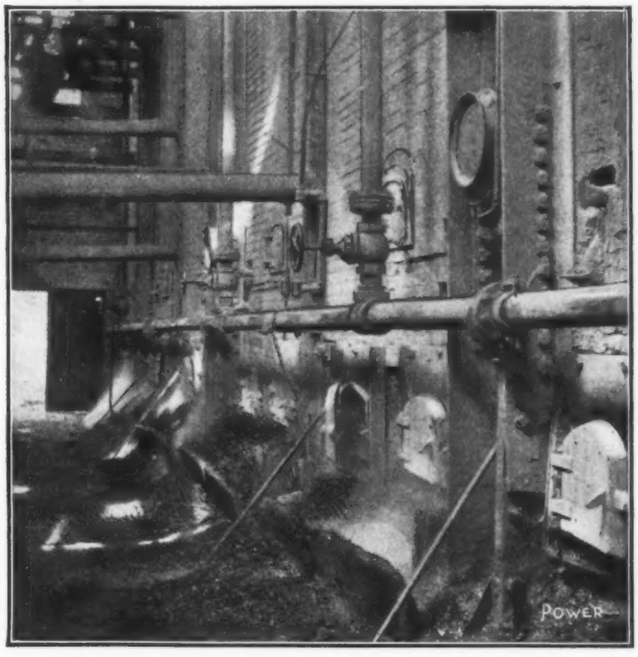


FIG. 2. NO ATTEMPT HAD BEEN MADE TO KEEP THE FLOOR CLEAR OF COAL

corroded through the metal and water, leaking from the header caps, I suppose, was running down the boiler front." (Fig. 3.)

"Well, that goes to show that the men were neglecting matters. Boiler settings, fronts and doors should be kept in order. If cracks exist in the setting, air will leak into the combustion chamber where it is not wanted. It cools the gases, and does no good."

"From what I have seen and heard, I should think that it would be a paying investment for some of these mine operators to hire a first-class man to take charge of their boilers—one who would make it his business to

keep the men up to a standard and the boilers in condition. Then the water in many instances is bad, so that scale and its attending troubles must be met.

"I knew of one superintendent, a bright chap, who used a simple means of keeping scale out of his boiler, one that most engineers would have condemned, but he claimed it worked all right, and I have seen his scheme worked out.

"This man had 1200 hp. in water-tube boilers and discovered through an accident that black strap oil, such as is used to oil mine-car wheels, would prevent scale from adhering to the boiler tubes.

"It happened this way: One of the men, after cleaning a boiler, accidentally spilled some of this black strap oil into the tubes. There was no time to remove it, and the boiler was put into service. When it was again cut out for cleaning, it was found that the tubes were clean. This caused the superintendent some surprise, who, after a little speculating, decided it was due to the oil that had been spilled in the boiler at the last cleaning day."

FIG. 3. THE TUBE DOORS OF THE BOILERS ARE CORRODED AND THE HEADER CAPS LEAKING

"I supposed oil was a dangerous thing to put into a boiler. There have been a good many dollars spent in oil separators just to keep it out of the exhaust steam.

"Yes, I know, but this superintendent has used oil in the boilers of every plant he has had since his discovery and he has found that it did the work in every instance.

A 10-gal. tank was placed above the heater. The tank was piped to a lubricator sight-glass, the bottom outlet of which was connected to the suction pipe from the heater to the boiler-feed pump. The sight-feed was set so that half a pint of oil would feed to the boilers in 24 hr. He told me that he now cleans 12 water-tube boilers in eight days, whereas if formerly required three or four days to clean one."

"I'll bet that man had a well kept plant, for from what you have told me he is a man who thinks and acts."

"Right you are," answered the fireman, arising to bid me good-night, as I opened the office door; "he is one man who knows what is going on."

As I passed through the boiler room on my way out, I noticed that the men were just as alert and attending as strictly to their work as they had been when I entered the plant, which emphasized the fact, to me at least, that a well organized boiler-room force is a paying investment, and that a boiler room left to shift for itself and attended by men who care nothing about its economic operation is a losing proposition, no matter how poorly the men may be paid.

The Aftermath

In February, 1905, Congress passed an act, granting to the Keokuk & Hamilton Water Power Co. rights to construct and maintain, for the improvement of navigation and the development of power, a dam across the Mississippi River from Keokuk, Iowa, to Hamilton, Ill. Congress was induced to accord this privilege by representations that the building of such a dam would greatly aid in the navigation of the river, that the Government would save a large sum in the annual cost of maintenance and operation of the lock at the Des Moines Rapids, and that the development of waterpower there would be of great benefit, not only to the immediate neighborhood, but to the commercial and manufacturing interests of the country.

Now Congressman Rainey, of Illinois, proposes:

Whereas the authority or franchise mentioned above was assigned to the Mississippi River Power Co.; and whereas the Missisippi River Power Co. has now completed the dam across the river; and whereas the steamboat companies navigating the said river claim that the dam is a hindrance instead of a help to navigation, and that their boats have to wait until the power company lets down enough water to float them; and whereas the Mississippi River Power Co. and its subsidiary companies are now engaged in buying up electric-light plants within its sphere of operations in the States of Illinois, Missouri and Iowa, paying, therefor, in many cases, much more than said properties are worth, and thereafter rendering less efficient service than was formerly rendered, demanding the same or greater compensation therefor; and whereas it is claimed that the development of water power at the said dam has not been of great benefit to the immediate neighborhood, or to the commercial and manufacturing interests of the country on account of the poor service rendered by the Mississippi River Power Co. and its allied and subsidiary companies, and on account of the excessive compensation demanded by such company and its allied and subsidiary companies; and whereas in defiance of law, and without the permission of the Congress, the said Mississippi River Power Co., or some company operating under its control, has built a bridge across the river, further obstructing navigation; and whereas Congress got nothing from the company for granting the privilege, other than the promise of said company to so construct and operate the dam and locks as to greatly aid navigation, and as to be of great benefit to the immediate neighborhood and to the commercial and manufacturing interests of the country, but reserved the right of repeal:

BE IT RESOLVED, that the committee on Interstate and Foreign Commerce of the House of Representatives be, and the same hereby is, directed to inquire into the same, send for books, papers and documents, summon witnesses, take testimony, with a view to determining whether or not said act ought to be repealed, or whether or not said act ought to be altered or amended so as to provide for an adequate compensation to the Government for the valuable privilege granted.

Editorials

New Jersey's Good Sense

New Jersey should rejoice that she is not to be burdened with a recently proposed boiler-inspection law, as the bill failed to pass in the legislature. It did not provide for a standard of design or installation; it did not make it necessary to determine by civil-service examination the qualifications of those who might be appointed inspectors; it made no exception of boilers under insurance inspection.

New Jersey needs a boiler-inspection law, but she does not need or want a law that does not equal the best. When New Jersey or any other state seriously considers having boiler laws, the bill should authorize the creation of a board of boiler rules. Let the latter adopt the Massachusetts rules, which will have the support of manufacturers of boilers, boiler-insurance companies, owners and engineers. These rules have been so changed and revised that now they meet all conditions, particularly those that are common to every state. Ohio and Detroit, and one or more of the Canadian cities, have adopted these rules and we understand that the Phillipines Commission recommends them.

There is every reason why boiler laws should be uniform throughout the country and none why they should not.

Smoke Means Waste

On the text over the cartoon this week we could preach quite a sermon, but we have referred to it so often editorially and the picture in itself is so eloquent that it scarcely seems needful to add more. There is one phase of the subject, however, and in a measure it is the keynote of this week's illustration, that does deserve emphasis. This is the fact that although "smoke means waste" is well known to so many, it is usually those who are most concerned that fail to appreciate it. They are inclined to think that the only reason for keeping their stacks from smoking is to avoid the complaints of the neighbors that they are maintaining a nuisance. Good and sufficient as is this reason, there is another that, even in the absence of this one, would be excuse enough for the exercise of every endeavor to stop smoke and that is, reverting again to the text, that "smoke means waste."

Some are indifferent to the black soot they scatter and are incensed at the ordinances directed against them because they fancy that it will cost them money to prevent smoke. For all the world like children who cannot see that the restrictions imposed upon them by their parents are generally for their own good, these short-sighted owners of smoking chimneys think that the measures taken to have the smoke stopped are in the interests of those who have smoke-abating devices to sell, if not deliberate persecution, whereas, if they but knew it, their own best interests will be served by cutting out this waste of money that is indicated wherever a stack is emitting black smoke.

Where is the plant owner who would not take immediate steps to stop it if he learned that his coal pile was being robbed? Would he wait for the city authorities to compel him to put an end to the thieving? Yet substantially he is doing that very thing when he continues to operate a plant that is discharging unnecessary volumes of dense smoke. The inexcusable part of it is that he himself is the robber and hence has it easily in his power to stop the theft.

This is not to say that all smoke can be prevented. No one who has studied the problem would even maintain that every bit of black smoke can be avoided, but under proper conditions and normal operation there should be very little of the time when an observer standing outside could tell from the appearance of the top of a stack that a plant is in operation.

For the benefit of any who may not see the analogy between a robbed coal pile and a smoking chimney, it may be briefly and simply explained. The visible part in smoke is nearly all carbon, either as soot or cinder, and carbon is the principal combustible part of coal, i.e., the useful part, the part capable of yielding heat. Carbon completely burned forms an invisible gas, carbon dioxide, therefore, whenever the gases from a stack show black they contain carbon which indicates that complete combustion has not taken place in the boiler furnace. In other words, all of the available heat in the coal has not been realized. It is the same as though the corresponding part of the coal fed into the furnace had been thrown away, for, although it has passed through the furnace, it has been thrown away up the stack beyond recovery. Is this, then, so very different from robbing the coal pile?

The owner who, through ignorance, allows conditions to exist which are not favorable to the most economical operation of his boiler furnaces—and black smoke from the chimney mouth is the unmistakable index of such conditions—although he is unwittingly robbing himself, is nevertheless stealing from his own coal pile. When he raves at his coal bill, like the man in the picture, he should vent his ire on himself, if he only knew it, and take kindly to the suggestions of the smoke inspector when the latter calls to remind him of his offending chimney. The inspector is a friend indeed if he can show him how to save the dollars that are escaping in the smoke.

It is not the purpose herein to discuss the various means for reducing smoke and thereby saving money. The situation in any individual plant calls for specific treatment. It is the part of the expert to diagnose the trouble and prescribe the remedies. POWER has shown in the past, and will continue to show, what are the principles governing smokeless combustion and what means have been successful in certain installations. How to get rid of the smoke, however, is not our main concern at present. What seems to be the most immediate difficulty is to get the owner properly aroused to the truth that "smoke means waste."

Temperature Variations in the Steam Plant

How many engineers have ever taken the trouble to ascertain the approximate difference in the temperature of steam and water in making a cycle from the boiler, through the various power-plant units and back to the boiler? Probably not many, yet the subject is of interest, and should be known to every power-plant operator.

Every steam plant is different, because the size of generating units, length of piping and design, and efficiency of the pipe covering will have a marked effect on the reduction of heat in the steam in doing work and from condensation and radiation.

From the moment combustion of fuel in the furnace takes place, transfer of heat, given up by the coal to the water in the boiler, occurs. The average temperature of a boiler furnace is about twenty-five hundred degrees, and the temperature of the furnace gases escaping to the chimney is generally between four hundred and six hundred degrees. The difference between furnace and chimney temperatures represent the heat absorbed by the brick boiler setting and by the water in the boiler. The greatest drop in temperature occurs between the furnace and second pass of a water-tube boiler; the drop is much less in the following passes.

When steam is admitted to a pipe system the temperature and pressure drop, due to radiation and pipe friction. The temperature of the steam at 164 lb., absolute, in the steam space of the boiler is, say, three hundred and sixty-six degrees. In the average steam plant the drop in temperature will be at least two degrees. Entering the high-pressure cylinder the temperature of the steam, in doing work, is reduced to approximately two hundred and fifty-six degrees, and exhausts to the low-pressure cylinder at two hundred and forty-four degrees, when the temperature is again reduced, this time to one hundred and ninety degrees. It passes to the condenser at one hundred and twenty-four degrees, a total drop of two hundred and forty-two degrees. A further drop in temperature occurs in the condenser, where the steam is condensed to about one hundred degrees at which temperature it passes to the hotwell in the form of water.

At this point of the cycle the exhaust steam of the auxiliaries is used to bring the hotwell water to a higher temperature before returning it to the boiler as feed water. If the steam auxiliaries use steam at boiler pressure its temperature will be three hundred and sixty-four degrees and will exhaust to the feed-water heater at about two hundred and nineteen degrees, which will raise the hotwell water to about two hundred degrees in passing through the heater. At this temperature it is discharged back to the boiler at one hundred and sixty-six degrees less than the original temperature of the steam supplied to the engine.

If feed water is taken from the city main or a source of supply other than the hotwell at, say, seventy degrees, the exhaust steam from the auxiliaries will be used to raise the temperature, but the water would go to the boiler at a lower temperature than if hotwell water were used with the same amount of exhaust steam.

The foregoing are approximate figures that would obtain in the average steam plant, with water-tube boilers and compound-condensing engines, using saturated steam at absolute pressure. The insert accompanying this issue of POWER shows such an installation in section with the temperature of the steam and water designated at different points in the piping and steam units.

Taking the Floor

Scott and his brave party trod over frozen snows and icy wastes, and died of starvation and exposure in their efforts to add to the store of human knowledge. Daring men have ascended to dizzy heights and fallen to their deaths to gain the experience which makes flight by heavier-than-air craft the success it now is. To add to the recorded knowledge of botany, Humboldt climbed mountain peaks until blood flowed from his nostrils, and, faint in the rarified air, he was forced to descend.

These men and many others have done these things that they might give to the world a better understanding of the planet which is our abode. Their reward was honor, simply honor. There was no salary attached to the efforts made.

How weak, how small, are those who, feeling the need for more knowledge of their craft, surrounded by every means for obtaining that knowledge, content themselves to plod in ignorance for fear they will expose themselves to criticism for asking questions about that which they wish to know. These men must blaze no new trails; others have done that for them. The path is lighted by recorded knowledge and the hand of Opportunity beckons them on to partake of the fruits of accomplishment.

In every power-plant engineers' organization, there are men who want to know more, but are reluctant to seek from those of their fellows who are only too glad to give. Enough of these reluctants in an organization will soon ruin it. It will die from non-use and they themselves are the sufferers. It is the men who ask, who seek to know, that keep an organization alive by their questions and participation in discussions. The man who is afraid to take the floor to ask questions starves himself of information that his mental appetite craves.

Let those who realize their weakness in this direction make better use of the opportunities that are presented by every discussion on the meeting room floor. This season is but half gone and many more are to come.

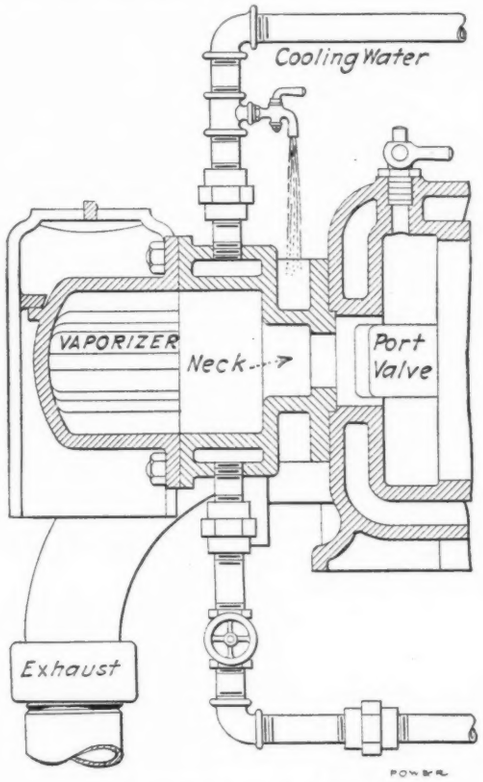
The movement in favor of the passage of uniform laws relating to the construction and inspection of steam boilers by the legislatures of the various states is being taken up by the locomotive companies, as well as by the manufacturers of boilers for stationary purposes. It has also attracted some attention from the Association for Uniform State Laws, and is likely to be brought forward at the next congress of the association. The American Society of Mechanical Engineers has a committee upon uniform boiler specifications which is also interested in this phase of the subject. With such backing, this legislation which POWER has been urging for the past quarter of a century should go rapidly forward.

Time's up, gentlemen, on that test of the Hall of Records Building in New York. What's the verdict, Isolated or Edison?

Correspondence

Prevents Preignition in Oil Engine

The illustration, Fig. 1, shows the manner of changing the circulating-water piping on a crude-oil engine of the vaporizing type so as to prevent preignition caused by an overheated part. As the interior cooling did not extend to this point a tee was inserted in the discharge pipes of the outgoing circulating-water line and a small pipe inserted, having a small valve to enable one to regulate the amount of water flowing. This pipe discharged the water on the outside of the small neck of the vaporizer, which would become so overheated on heavy loads, that at times the casting would crack at this point.



How the Neck Was Cooled

In this type of engine the fuel is injected on the suction stroke and vaporized by heat and compression, and at the proper pressure and temperature the charge will fire by coming in contact with the hot cup which is not water-jacketed. The indicator diagram, Fig. 2, shows the engine working under full load with the water flowing upon the neck to keep the engine in its normal condition, while Fig. 3, shows the engine working on a lighter load, and having the cooling water cut off from the neck. In this condition preignition occurs and forms the loop in the diagram.

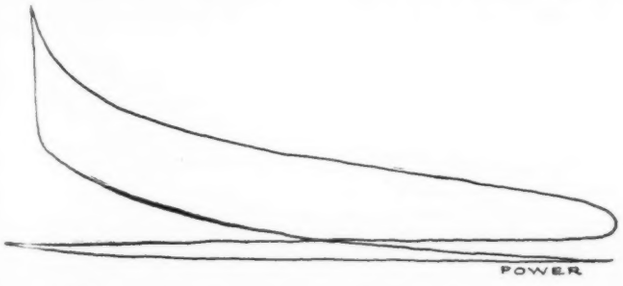


Fig. 2. With Water Applied to Neck

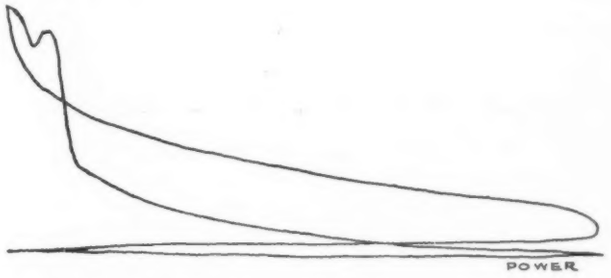


Fig. 3. With Water Not Applied to Neck

C. R. McGahey.

Baltimore, Md.

Peculiar Pump Trouble

In a plant where I was engineer there was a pump of the single-acting type for supplying cooling water to an ammonia condenser. This pump worked smoothly and I did not pay much attention to it for the first few days, but finally my attention was called to it by the manner in which the water acted in the jackets of an upright ice machine.

Every little while those jackets received a lot of air and the water would splash over the machine. As this had been a common occurrence, I was told not to bother about it, but I wanted to know where so much air was coming from, particularly as there was no chance for the water in the reservoir to get below the suction line. Finally I discovered a ¼-in. pipe tapped into the suction line close to the pump and ending in the basin-like frame of the pump. There was a valve on this line which appeared to be leaking badly. I took the bonnet off and found that the end of the stem had been cut off. I put in a new valve and upon closing it was surprised when the pump began kicking and pounding. With the valve open again the pump ran as smoothly as ever. I tried closing that valve fully 20 times during the day and the result was always the same. I was told that air must be admitted to the suction to keep the pump going.

At the first opportunity I examined the valves and packing in the water end. They looked all right, but a few days afterward I put in a new set of valves and springs and also new plunger packing. Still the trouble remained, and was not located until the pump was taken apart.

At some time a new brass sleeve had been fitted into the water cylinder and the man who did the job had taken his measurement from the frame-end head to the outside end of the barrel instead of just the length of the barrel. He did not figure how the water was to get into the frame end of the water cylinder from the suction chamber. There was a small opening, but not enough to admit the water fast enough, so that air was used to fill in. The sleeve was badly worn and as it would not last much longer I took it out and ran the pump without a brass lining. To do this two large washers were made to increase the piston diameter so that the packing would hold. The result was a smooth running pump that did not have to be filled with air.

A. G. Solomon.

Chicago, Ill.

Circuit-Breaker-Bell Alarm

Due to the scattered arrangement of our power equipment and to various duties of the engineer calling him away from the engine room, it became necessary to install an alarm system of some kind which would call the attendant to the traveling-crane feeder panel whenever the circuit-breaker was tripped. We, therefore, devised the arrangement shown.

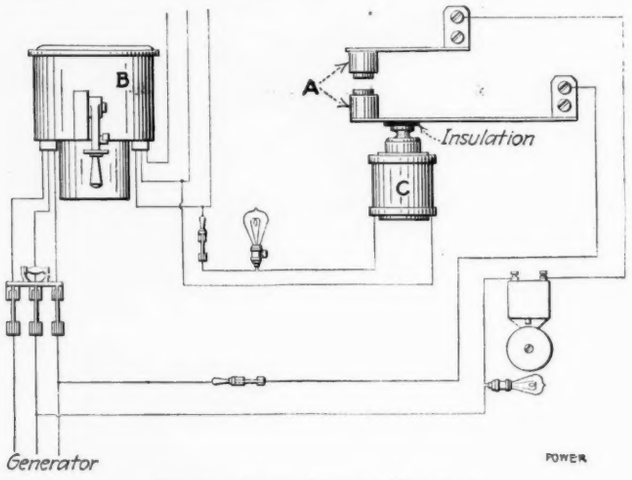


Diagram of Alarm System

An old 240-volt call bell which had previously been used as a ground detector was repaired and mounted in a convenient place where it could be easily heard from either of the two engine rooms or the fire room. It was connected to the generator side of the oil switch through a 120-volt lamp and carbon-tipped contacts *A*. These contacts were made by inserting small pieces of arc-light carbon into the brass terminal caps of an old 30-amp. cartridge fuse, leaving about ⅛ in. of the carbon projecting. These caps were then soldered to pieces of thin spring brass and mounted on the wall near the oil switch *B* so that the carbons were about ½ in. apart. A small shunt-trip coil *C* taken from a discarded circuit-breaker was mounted, as shown, and connected through a 240-volt lamp to the line side of the oil switch. When the coil is energized, as when the main circuit is closed, the magnet plunger is drawn down and the spring of the brass mounting of the lower contact holds the contacts apart, thus breaking the bell circuit. When for any reason the oil switch is tripped, the shunt trip coil is no longer energized and the plunger is expelled by a spring, forcing the carbon contacts together against the slight spring of the lower contact mounting, thus closing the alarm circuit which lights the 120-volt lamp and rings the call bell.

M. E. Merriman.

Boonton, N. J.

Cost of Power from Hydro-Electric Stations

In the issue of Feb. 10, page 204, Ralph E. Somers says that the cost of a horsepower for a year of 3600 hr. would be some $20. This would be simply the charge for current. As the plant would have to supply its own switchboard, wiring, motors, controllers, belts, etc., upon the cost of which interest, depreciation and taxes must be charged, and would be at some expense for attendance and supplies, the total cost per horsepower-year, comparable with that generated by a steam plant at the mill, would be somewhat in excess of the $20 quoted, would it not?

S. B. Stebbins.

Atlanta, Ga.

Removing Frost from Direct-Expansion Coils

The idea is good in Mr. Thurston's article under the above title, in the Jan. 6 issue; it puts me in mind of a brewery refrigerating plant in which I once worked. The plant was large and equipped with reserve machinery so that a compressor could be started to take the place of one out of order, as continuous operation was necessary. Now and then, when the ice on the coils became so heavy that the valves could not be closed, the men knocked it off with hammers and chisels. This was bad practice; Mr. Thurston's hot-gas line would have been better.

Eventually, a different plan was adopted. The night engineer was told to close one of the valves on the liquid line controlling three rooms. The following morning the ice around the pipes was soft and easy to knock off. After all the ice had been removed, the ammonia was turned on again. The following night another valve controlling three other rooms was closed, and the valve that had been turned off the night before was again closed. The light coating of ice on the coils was completely melted off in two hours. By this time the temperature in the six rooms had not risen more than 1 deg. R. The ammonia valve controlling the first three rooms was then opened and the thermometer read 1½ deg. R. lower in the morning in these rooms than it did when the heavy ice was on the coils and the ammonia on all night.

After the heavy ice had been knocked off all the coils in succession, we shut down every night until the light coating of ice, caused by about 22 hr. run, was melted off. We could even afford to shut down in the hottest weather and still have the rooms 1 to 2 deg. R. lower in the morning than they had been under the old method of operating. Some brine was used for cooling beer, and this went up 2 to 3 deg. R. in the two hours the plant was shut down, but by morning the temperature was back

to normal. In storage houses requiring a constant temperature, Mr. Thurston's method could not be used for removing the ice, but would be convenient for pumping out condenser sections separately.

WILLIAM L. KEIL.

Philadelphia, Penn.

Mr. Thurston's article appears rather impracticable to me. It is certain that ammonia gas at 200 deg. will take the frost off coils if it reaches them at anywhere near this temperature, but will the hot gas go into the coils hot enough to do any good? I have heard of this system being used, but I have never seen it operate satisfactorily. In my opinion, half a dozen laborers, directed by an engineer, will do this work better and in much less time.

The frost can be melted free from the coils by shutting the suction valve and leaving the expansion valve open, so that the coil will partially fill with liquid. This method, however, is not to be recommended. The chance of starting leaks in the flanges and other places is great, with the resultant loss of ammonia and encountering other disagreeable features. Care must also be taken in again getting the liquid ammonia out of the coil and through the compressor without doing damage. While all this is going on the ice machine is doing little, if any, good to the other rooms which require cooling.

Expansion valves are usually ½ in. in diameter and there is always some ½-in. pipe between the expansion valve and the coil of 2-in. pipe. The hot gas will cool considerably while traveling from the ammonia condenser to the ½-in. expansion valve. Then in passing through a few feet of ½-in. pipe and through a ½-in. valve in the cold room, more heat will be lost. Then the gas will lose a large part of its remaining heat when it enters the 2-in. coil, due to the expansion at this point. The frost on the coil and the low temperature of the room will finish the job, and the hot gas from the condenser will be cool liquid before any frost drops off.

I once saw a coil cleaned by someone who accidentally shut the suction valve and let the expansion valve stay open until the coil was full of liquid and must have had condenser pressure on it. In that case a gasket was blown out of a 2-in. flange and a lot of ammonia was lost. A gang of men was driven out by the fumes and the work was delayed several hours.

In another case, the heavy frost fell off of about 60 ft. of 2-in. pipe in the center of a coil 1000 ft. long. It was found that the pipe had been blocked nearly solid by a slug of solder which had entered the pipe when the flanges were sweated on.

Both of these jobs were accidental, but they are enough to make me decide that it is a poor way of getting results. Clean the frosted coils with scrapers, and the compressor can be kept in operation on some other part of the plant at the same time.

A. G. SOLOMON.

Chicago, Ill.

Mr. Solomon's criticism is not quite justified, as thawing off the refrigerator coils by means of the hot vapor from the ammonia compressor can be satisfactorily performed. It is only necessary to shut off the suction valve and allow the hot vapor to enter the coils. By the time the pressure in the coils rises sufficiently to cool and liquefy the hot gases, much thawing can be done; in fact, more ice can be thawed off in this way than with the liquid entering from the expansion valve.

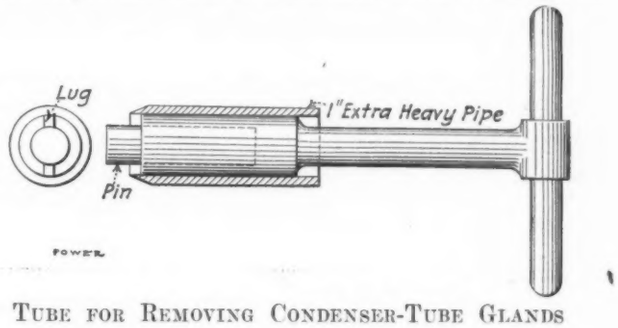
In all these thawing-off systems, it is necessary, when starting up the coil again, to be careful to open the suction valve slowly, so that the refrigerating machine will not be flooded with liquid and perhaps be damaged.

FRED OPHULS.

New York City.

Tool for Removing Condenser-Tube Glands

The accompanying drawing is of a tool used for removing condenser-tube packing glands. The body is bored to the size of the inside diameter of the tube. A pin is fitted in the bore with the end projecting so as to enter the tube about ¾ in. A piece of 1-in. extra-heavy pipe is bored out and slipped over the tool and packing gland to prevent the slot in the latter from breaking out.



TUBE FOR REMOVING CONDENSER-TUBE GLANDS

I made a tool of this design for taking out old glands, and find it better than the common gland tool. If the lugs break off the tool, it is only necessary to pull out the pin and file or saw new lugs. I case-harden the lugs to give additional strength.

F. R. LEWIS.

Peoria, Ill.

Throwing Oil

On an old-style dynamo having no oil-throwing device inclosed in the bearings, a brass plate about $\frac{3}{16}$ in. thick was affixed to the end of the commutator and insulated from it by mica. The idea was to throw off any oil which would creep along the shaft. Sometimes the machine sparked and sometimes it did not. However, I decided to investigate.

Upon removing this brass plate I found that the oil creeping along the shaft had also crept between the layers of mica and spoiled the insulation. At two or three places a small hole had been burned through the mica, which allowed a spark to start. I put a piece of thin rubber packing in the place of the mica and had no further trouble.

If there is a fairly large collar on a high-speed armature shaft it is a first-class spraying device, and with the suction of the air through the armature, the coils will soon become soaked with oil. The easiest way to obviate this is to put a small sheet-metal oil guard over the collar; this will catch the spray and allow it to drain to the bottom of the bearing.

W. BURNS.

Govan, Scotland.

Inquiries of General Interest

Shifting Brushes of a Generator—What is the effect of shifting the brushes of a generator from the neutral position?

C. B.

If shifted too far, sparking will result and the voltage will be reduced.

Current Density with Carbon Brushes—How much current may safely be carried per square inch of brush contact with carbon brushes on a small 115-volt generator?

J. F. B.

With the commutator true and smooth and brushes ground to a good fit, it is considered by many that 35 amp. per sq.in. of brush contact is all that should be allowed for carbon brushes.

Negative Lap with Double Eccentric Corliss Valve Gear—Why are the steam valves of a double eccentric Corliss engine given a negative lap?

F. C. H.

The range of cutoff for the Corliss valve gear is from the beginning of the stroke to half stroke or less. When a longer cutoff is desired the wristplate must be moved by an eccentric with negative advance and the steam valves have a clearance instead of lap.

Foot-Pound Resistance of Steam Fitting—In testing the strength of close nipples when inserted in a steam fitting what is meant by "resistance in foot-pounds?"

W. R.

Resistance in foot-pounds refers to the moment or leverage resisted by the fitting, expressed as a product of force or test weight in pounds multiplied by its lever arm or perpendicular distance in feet of the action line of the force from that point of the fitting under consideration.

Moisture in Steam—What percentage of moisture is contained in steam discharged from boilers in ordinary use?

H. L. R.

When horizontal return-tubular boilers of average proportions or water-tube boilers having drums that afford ample disengagement surface are fed with water free from ingredients which cause foaming, and the boilers are not driven beyond their normal capacities, nor the water level carried too high, then the steam discharged will usually contain not more than about 2 per cent. of moisture.

Rotary Transformer and Motor-Generator—What is the difference between a rotary transformer and a motor-generator?

L. N.

Both serve the same purpose—to convert direct into alternating current, or vice versa. A motor-generator set is a motor and a generator each complete in itself with their shafts directly coupled, while in a rotary transformer, or rotary converter, the alternating and direct-current windings are in the same machine.

Advantages of Suspended Boiler—What are the advantages of suspending horizontal-return tubular boilers as compared with supporting them on the side walls of brick settings?

C. D.

The setting of a suspended boiler can usually be arranged to take up less space; the brick work and boiler shell may expand and contract independently; brick work may be removed and repaired without endangering the supports of the boiler; the walls are less likely to settle or crack; and equalizing levers may be employed for sustaining desired proportions of weight at the different points of suspension.

Kerosene in Boilers—What are the objections to the use of kerosene in boilers for preventing boiler scale?

C. N.

The principal objections are that it is likely to cause leaking of calked joints, around rivets and of the expanded joints of tubes. Leaks thus induced are difficult to stop. Further objections are that, with some feed waters, the use of kerosene is accompanied by oily deposits which are likely to result in overheating or burning of the material of a boiler and that the volatile oil carried over with the steam causes leaking of steam-pipe joints and softening and leaking of packings.

Consumption of Gasoline—What amount of gasoline would be required per hour to run a 25-hp. engine loaded two-thirds of its capacity?

C. H. L.

It is usual to consider the consumption of a gasoline engine as one pint of gasoline per horsepower-hour when the engine is in good condition and running at full load. The fuel consumption is slightly greater when running at lighter loads. Assuming, then, that the gasoline consumption at two-thirds load would be 1.2 pints per horsepower-hour, the total hourly consumption would be $1.2 \times 0.66 \times 25 = 20$ pints per hour.

Obtaining Shorter Cutoff—How can the cutoff of a Corliss engine be shortened?

R. T. R.

The governor automatically adjusts the cutoff to the mean effective pressure required for maintaining the speed, and as, for a given horsepower developed, the mean effective pressure is inversely as the speed, the governor will shorten the cutoff if the speed of the engine is increased, but with the same load and same speed the governor will automatically adjust the valve gear to a point of shorter cutoff for an increase of the initial pressure or a decrease of the back pressure on the piston.

Large and Small Calorie—What is the distinction between "large calorie" and "small calorie"?

L. B. B.

The large calorie is the French thermal unit and is that quantity of heat required to raise the temperature of one kilogram of pure water from 4 deg. C. to 5 deg. C. It is the usual "calorie" of engineering, being equal to 3.968 B.t.u. The small calorie is the thermal unit of physicists, being the quantity of heat required to raise the temperature of 1 gram of pure water from 4 deg. C. to 5 deg. C.; hence the small calorie is the one-thousandths part of the calorie generally used in engineering computations.

Equal Vacuum for Different Barometric Readings—With a barometric reading of 27.4 in., how many inches of vacuum would have to be obtained for the same condenser pressure as with 26 in. of vacuum at sea level?

H. B. F.

For the same temperature of atmosphere surrounding the mercury gage and barometer in each case and assuming the atmosphere at sea level to have a barometric pressure of 30 in., then a vacuum gage reading of 26 in. at sea level would be 30 in. — 26 in. = 4 in. of mercury column pressure for the given gage temperature; hence for a barometric reading of 27.4 in. the same absolute pressure would exist when the vacuum gage showed 27.4 — 4 = 23.4 in. of vacuum.

Wattless Current—What is meant by wattless current? How may it be detected, and does wattless current represent wasted energy?

H. L. M.

In an alternating-current circuit containing inductive resistance, counter-electromotive force is set up which opposes the flow of current. This causes the maximum values of the current and voltage to occur at different times, in other words, the current is said to lag behind the voltage. The total current is not effective. The ineffective part is called wattless and, expressed graphically, the component of the current at 90 deg. to the electromotive force is wattless, as it can do no work. It may be detected by a power-factor meter or by noting the difference between the wattmeter reading and the product of the voltmeter and ammeter readings.

Wattless current does not represent wasted energy, but it leads the line and limits the current-carrying capacity.

Engineers' Study Course

The Slide Rule--II

LAST LESSON'S ANSWERS

1. Set the right-hand "1" of the C-scale on 93 of *D;* under 17 of *C* is found 158. By inspection it is seen that 0.0093 is very close to 0.01 and $^1/_{100}$ of 17,000 would be 170, so the answer will have three whole-number places, or

$$17{,}000 \times 0.0093 = 158$$

2. Set the hair line of the runner on 316 of *D.* Slide *C* until 273 (the last figure, "3," will be 1½ of the smallest divisions) is under the hair line. The answer under "1" of *C* is 1157 (the last figure is estimated) on *D.* By inspection, 273 into 0.0316 will require three ciphers after the decimal, so the answer is

$$\frac{0.0316}{273} = 0.0001157$$

3. In problems of this sort generally it is better to take a division first then multiplication and so on alternating. It reduces the number of resettings of the slide, as will be explained later, although it will not in this particular case. Set the hair line on 605 (the first small division after "6") of *D.* Move slide until 437 (the "7" is estimated as $\frac{2}{5}$ of the second smallest division after 43) on *C* is under the hair line. Under "1" of *C* is 1382 on *D* which is the quotient and must still be multiplied by 921. The latter on *C* is off the scale to the right, so the slide must be shifted end for end by first placing the hair line over the left-hand "1" of *C;* then bringing the right-hand "1" of *C* under the hair line. Now slide the hair line to 921 on *C* (the "1" is estimated) and under the line on *D* is the answer 1275 and it is clear that it is a whole number and there is no decimal point to be placed.

4. The formula required is the familiar

$$hp. = \frac{PLAN}{33{,}000}$$

The *P* is given 26.7 lb. The length of stroke is 10 in. or $\frac{10}{12}$ ft. = *L.* The area is $10^2 \times \frac{\pi}{4} = 10 \times 10 \times 0.7854 = A$ and the number of strokes per minute is twice the number of revolutions per minute, or $346 \times 2 = N$. Then the equation is

$$hp. = \frac{26.7 \times 10 \times 10 \times 10 \times 0.7854 \times 346 \times 2}{33{,}000 \times 12}$$

Quite a little canceling is possible as a short cut; the three "10's" into the "33,000" the "2" into the "12" and the "6" left into 0.7854; so that the equation before using the rule at all can be simplified to

$$hp. = \frac{26.7 \times 0.1309 \times 346}{33}$$

Set the hair line on 26.7 *D;* bring 33 of *C* under the line; move the line to 1309 of *C;* bring left-hand "1" of *C* under the line; move the line to 346 on *C.* The answer is now under the line on *D,* or 366. A 10x10-in. engine must be more than 3 hp. and less than 300 so the answer is 36.6 hp.

5. If the coal consumption is 10 lb. per sq.ft. of grate area per hour, it is 10x27 lb. per hour, and per square foot of heating surface

$$\frac{10 \times 27}{920} = \frac{27}{92} = 0.293\ lb.$$

The problem could also be stated as an inverse proportion

$$920 : 27 : : 10 : x$$

and solved as later explained for proportions.

It is to be noticed that it was not necessary to carry the decimal point in mind through any of the problems.

THE SLIDE RULE CONTINUED

To solve $117 \times 57 \div 45$, one can multiply 117 by 57, and make a resetting to divide by 45. It is, however, much shorter to set the hair line on 117 of *D* and bring 45 of *C* opposite it, then the quotient 2.6 is found on *D* under the "1" of *C.* Without resetting the slide, move the hair line to 57 of *C* and read the final product of *D,* i.e., 148.2. It is impossible to read the rule so exactly as to know that the product is 148.1, 148.2 or 148.3, but the product of two numbers ending in a 6 and a 7 respectively must end in a 2, so that this determines the fourth figure. The application of this principle will enable any product of two 2-figure numbers to be read with absolute precision on the rule. Thus 83×94, it is impossible to read much closer than 780 on the rule, but mentally saying $3 \times 4 = 12$ enables us to give all four figures 7802. The fewer settings to be made by the rule, the greater the accuracy.

Proportions are readily solved on the slide rule. For instance, 74 : 67 : : 8.2 : *x.* A simple rule is: "Set the first on the second; under the third is found the fourth. For example, set the hair line on 67 of *D;* bring 74 on *C* under the line; then move the line to 8.2 of *C* and under it on *D* is 7.43, the unknown fourth term.

Square roots and squares on the slide rule are matters of a look only. The figure under the hair line on *D* is the square root of the figure under the hair line on *A.* Here the decimal point must be considered a little more. The figures on the left half of scale *A* represent all numbers from 1 to 9, 100 to 999, 10,000 to 99,999, i.e., all numbers having an uneven number of figures. The right half of the scale represents all numbers from 10 to 99, 1000 to 9999, etc.; all numbers of an even number of figures. If one forgets the rule, try it out with 4. Set the line on the left-hand "4" and "2" will be found under it. Set it on the right-hand "4" and 6.325 (as nearly as can be read) will be found under it.

$$\sqrt{4} = 2;\ \sqrt{400} = 20;\ \sqrt{40{,}000} = 200$$

$$\sqrt{40} = 6.324+;\ \sqrt{4000} = 63.24+ \text{ etc.}$$

Squares are the converse. Set the line on a figure on

scale *D*, and the square will be found above on scale *A*.

Cubes are obtained by repeated multiplication on the lower scale. To cube 3.1, set the hair line on 3.1 of scale *D*, put the left-hand "1" of *C* opposite, and read 9.61 on *D* opposite 3.1 on *C*. Leave the hair line set on 9.61 and bring the right-hand "1" of *C* opposite it, then read 29.79 on *D*. A second method: Set the hair line on 3.1 of scale *D*, and read 9.61 on scale *A* above. Set the "1" of *B* opposite 9.61 of *A*, and read the cube on *A* opposite 3.1 on *B*.

Obtaining the cube root seems complicated, but is nowhere nearly so difficult as the same operation with paper and pencil. First reverse the slide, see Fig. 1. Then consider all numbers from 1 to 10 represented by the left-hand scale on *A*, 10 to 100 by the right-hand scale on *A*, and 100 to 1000 by an imaginary scale out to the right of the rule. To get the cube root of 9, set the hair line over "9" on the left-hand scale *A* and bring the right-hand inverted "1" of the inverted scale *B* under

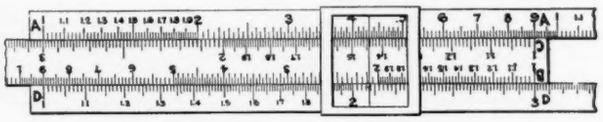


FIG. 1

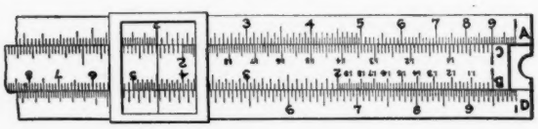


FIG 2

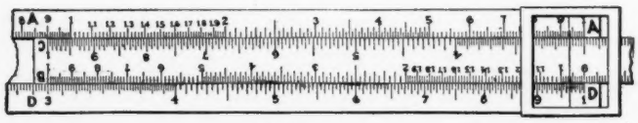


FIG. 3

it, move the hair line along until it covers the same number on scales *B* and *D*. In this case it can be seen immediately that it is near 2, as 2 on *B* is opposite 2.118 on *D*, and 2.24 on *B* is opposite 2 on *D*. But 2.1 on *B* is opposite 2.064 on *D*, showing this is too much; 2.05 on *B* is opposite 2.093 on *D*, too little; 2.075 on *B* is opposite 2.082 on *D*, still too little; 2.080 seems to be about right. (The correct answer is 2.0802).

To get the cube root of 90, set the hair line on the "9" (or "90") of the right-hand scale *A*, and bring the right-hand inverted "1" of scale *B* under it, as in Fig. 2; then, as before, move the hair line until the readings on *B* and *D* are the same. The 4 on *B* lies opposite 4.745 on *D*, and 5 on *B* lies opposite 4.245. The root lies between 4 and 5; 4.5 on *B* is opposite 4.47 on *D*; 4.475 on *B* is opposite 4.485 on *B*. This would indicate an answer of about 4.482. (The correct answer is 4.4814).

To obtain the cube root of 900, set the right-hand inverted "1" of scale *B* on an imaginary 900 out to the right of the scale, which means set the left-hand inverted "1" on the "9" on the left-hand A-scale, as in Fig. 3. The "9" on *B* is opposite "10" on *D*, and "10" on *B* opposite 9.48 on *D*; 9.5 on *B* is opposite 9.73 on *D*; 9.6 on *B* opposite 9.68 on *D*; 9.65 on *B* opposite 9.66 on *D*; so 9.655 is about the answer. (The true answer is 9.659, which indicates a high accuracy for this method of computation.

In this last case do not make the mistake of reading too far down the rule and attempting to find the answer again between 4 and 5. In this case it must be remembered that the "4" of the B-scale is the 40. In general this ambiguity must be avoided by remembering roughly that the cube root of 900 is near 9, not near 4. So, too, the cube root of 9000 would roughly be near 20, not near 40 or 50, where the *B* and *D* scales also give the same reading at about 4.480. That is, in cube and square root, as in finding the decimal point in multiplication, it is necessary to use a little discretion. So, too, the cube root of 90,000 is near 40 and not near 20 or 200 as might possibly be thought from a too quick look at the slide rule.

It was shown in the last lesson how, with the slide in its normal position, tables of multiples were given for each setting of the rule. With the slide inverted in the rule, as for cube root, but with the terminal "1s" brought opposite, a table of reciprocals is afforded, for each number on *A* will be above its reciprocal on *B*, or each number on *C* will be above its reciprocal on *D*. For instance, 4 on the left-hand scale *A* is over 25 on scale *B* ($\frac{1}{25} = 0.04$ or $\frac{1}{4} = 0.25$) and "5" on scale *C* is over "2" on scale *D* ($\frac{1}{2} = 0.5$ or $\frac{1}{5} = 0.2$).

A useful table available at one setting of the slide rule is that for areas of circles. If the right-hand "1" of *B* be set on $\frac{\pi}{4}$ (0.7854) of *A*, then if the hair line be set on any number on *C*, the area of the circle of that diameter can be read directly on *A*. (This should be tried.) For instance, opposite 2 on *C*, one finds 3.1416 on *A*, the area of a circle of a diameter of 2. On the other hand, with this setting, if the hair line is set on the area of a circle on *A*, the diameter is at once read on scale *C*.

Since a "table" is formed when the "1" of the slide is put opposite a number, any number of multiplications by a common factor can be made at one setting of the rule. Take the common factor on *D* or *A*, set "1" of *C* or *B* opposite it, and read the products successively without resetting the slide. Divisions usually take a fresh setting for each one, but if several different numbers are to be divided by the same number, e.g., 2.43, first get the reciprocal of the divisor $\frac{1}{2.43}$, which is found to be 0.412. Then multiplying the different numbers by this reciprocal is the same as dividing by the original divisor, and all of the operations can be done at one setting.

This by no means exhausts the capacity of a slide rule, as all sorts of trigonometrical problems can also be solved on it, but multiplication, division, raising to powers, extracting roots and solving proportions are the principal uses.

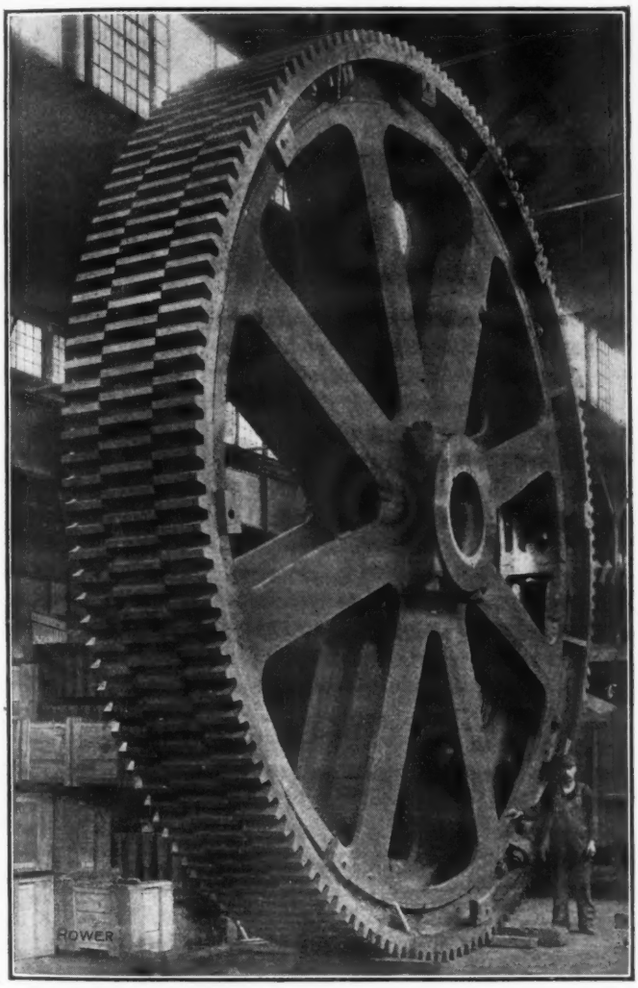
Study Questions

6. At one setting solve $\frac{33.4 \times 1.29}{0.492}$.
7. Solve the proportion $61 : 408 : : 32 : x$.
8. If the mean effective pressure remains the same, how much horsepower will an engine develop at 200 r.p.m. if it develops 45 hp. at 160 r.p.m.?
9. Find the square root of 42,200.
10. Find the cube root of 42,200.

Triple-Staggered-Tooth Steel Wheel

A steel gear, probably the largest of its kind ever manufactured, was shipped recently by the Mesta Machine Co., Pittsburgh, Penn., to the Inland Steel Co., Chicago, and will be used for driving a sheet mill. From this gear and pinion a single-stage speed reduction is obtained from the motor to the mill.

The gear is 22 ft. 8 in. in diameter, with a 38-in. face and 5½-in. circular pitch; the mating pinion is 2 ft. 11 in. in diameter; there are 154 teeth in the gear and 20 teeth in the pinion.



TRIPLE STAGGERED-TOOTH STEEL GEAR

The design varies from ordinary practice because the teeth are staggered in three sections. On account of the axial motion to which the drive is subjected it was necessary to use a spur gear. A herring-bone gear was not considered because of the unequal pressures that would be exerted on the side of the tooth face. It travels at a speed of 2000 ft. per min. and transmits 1600 hp. To meet the action of this high speed the gear was carefully cut, the teeth staggered, and the drive arranged to run in an oil bath.

The gear is built up of six parts. The center, including the arms, etc., carries the central rim segments of teeth; the two halves of the gear are bolted together, and the separate rims fastened by bolts running through the side of the central casting.

OVER THE SPILLWAY

JUST JESTS, JABS, JOSHES AND JUMBLES

Lots of folks know Leonardo da Vinci only as the painter of Mona Lisa, who was kidnapped and recently returned to her guardians. Lenny was a big mechanical engineer as well as painter. If you live near Hoboken (and some people have to), go to Stevens Institute on the evening of Feb. 20 and hear John W. Lieb's lecture on Da Vinci, M. E.

⋇

"Peace, honor, freedom and prosperity" are wished us in President Wilson's recent message. Makes a fine message. Now, if he can make it stick, we'll be "thanking you in advance, and remain yours very truly." We can suggest lots of other nice things, but we can't seemingly get away with them.

⋇

A highly peeved party, hiding behind the signature "Subscriber," calls us dishonest because we allowed an advertiser to fill a vacancy before the ad. appeared. Come out in the open, Mister, and let's have your name (even if it be Mudd!) A common-sense man knows that when a concern wants an engineer it wants him quick. Suppose this afternoon an ad. was inserted for tomorrow morning's paper, and the advertiser met Mister Subscriber an hour after, and hired him. Would this Mister howl dishonesty and refuse the job? Not on your CO_2 recorder he wouldn't. Subscriber? We don't believe we have one who even thinks we are not square.

⋇

There's a powerful lot of money put into one of Uncle Sam's fighting plants. Take the "Texas," for instance. She represents $15,000,000! But we must have peace, even if we have to fight for it. And it's the engines that keep this mass moving—give it impetus! Makes you throw out your chest, eh?

⋇

We asked a friend of ours, a boiler inspector, to send us some dope regarding a recent boiler-rules meeting. Here's his answer: "We had the Board, something to eat, nothing to drink—and the usual speeches." The lucidity of this account ought to help the operating engineer mightily. That's the reason we print it.

⋇

When we read that a mite of a baby had been sent through the mails" by the parcels post, rightside up and unharmed, to (sex unknown) its destination, we thought our parcels post was some punkins! Now, we are doubtful, for "Indian Engineering" says "The Postmaster-General of Bengal left for Siliguri on Monday by the Darjeeling mail."

⋇

WHEREAS, AND BE IT RESOLVED—

BY BILLY SPILLS

You've met up with one of those "whereas" things that they hang a Congressional bill on? It starts off with about 23 hand-picked and wrapped whereas-es, gathers impetus on a 200 per cent. overload of legal garbage (or is it verbiage?), and discharges at high velocity into the be-it-resolved hotwell.

Then, being a layman, you say, "What ther ———" (fill in to suit). And your mind harks back to the time brother Willie got his panties on 'hindside before—you didn't know if he was going or coming.

Just you turn over to page 238 and under the caption "The Aftermath," you will find an apt illustration. What damming the Mississippi would do for the folks on its sandbagged banks, according to the tell of the power company, would make Henry Ford look like two bits. Then about the time the dam dammed its hardest the industrial folks woke up. They started to sic the Congressional canine to barking up the whereas tree, and now he has brought down a full-grown resolve that measures 14 in. from the tip of its "whereas" to the end of its "resolved, further."

It is astounding how many good working American words can be hidden away in an 18-karat cluster of whereas-es and a solitaire be-it-resolved. Now, Congressman Rainey seeks to undo those things which were overdone and do over those things which were underdone.

In the meantime, we will save up further comment for a Rainey day, hoping that the Congressional sun will soon after dispel the clouds that at present hang threat'ning o'er the Mississippi.

How to Calculate the Losses in Gas Engines

By George W. Muench

SYNOPSIS—Simple calculations showing how to figure the heat balance of a gas engine with a degree of accuracy close enough for ordinary purposes.

Calculation of the heat losses in a gas engine is a matter of the simplest arithmetic and it is necessary only to understand a few principles regarding heat. In the following calculations no attempt is made to go deeply into the subject of heat or heat transfer; just enough is given to show how various heat losses are obtained.

The losses comprise the heat given up to the jacket water, that carried off in the exhaust gases, both as sensible heat and unburned gases, and radiation and conduction. When calculating the exhaust losses gases are dealt with and not water, which somewhat complicates the problem.

When obtaining the exhaust losses it is necessary to know the weight of a cubic foot of the gas, also its specific heat, which is the ratio of the heat required to raise that substance one degree to the quantity required to raise an equal weight of water one degree. The specific heat of air at constant pressure is 0.2375 and that of the exhaust gases may be assumed as 0.245. For accurate calculations, the exact specific heat of the mixture must be ascertained. The volume of mixture passed through the exhaust is found by multiplying the piston displacement by the number of explosions, and the temperature in the exhaust pipe is measured as near the engine cylinder as possible. The heat lost in the exhaust per hour is found by multiplying the weight of 1 cu.ft. of the mixture, by the cubic feet exhausted per hour, by the specific heat, and by the temperature change. This can be expressed in a formula as follows:

$$B.t.u.\ per\ hr. = WSQ\ (T - T')$$

where

W = Weight of 1 cu.ft. of mixture at exhaust in lb.;
S = Specific heat of the mixture;
Q = Cubic feet of mixture exhausted per hr.;
T = Temperature of the exhaust gases;
T' = Room temperature.

The radiation loss plus the loss due to incomplete combustion is found by subtracting the sum of the cooling-water loss, the exhaust loss and the heat turned into mechanical energy from the total heat supplied to the engine.

One B.t.u. is equivalent to 778 ft.-lb., and since 33,000 ft.-lb. per min. represents 1 hp.

$$B.t.u.\ per\ hr. = \frac{i.hp. \times 33{,}000 \times 60}{778} = 2545 \times i.hp.$$

Having determined the methods for finding the heat losses as well as the heat supplied to the engine, the next step is the heat or thermal efficiency. This is the ratio of the heat absorbed in work to the heat supplied to the engine by the fuel.

The heat losses are about as follows: Jacket loss, 30 to 50 per cent., with an average of 40 per cent.; exhaust loss, about 30 to 35 per cent., and radiation loss, about 5 per cent. The thermal efficiency varies from 15 to 35 per cent. with 20 to 25 per cent., a fair average.

The following problem covers a test of a four-stroke-cycle engine and in order to make the calculations complete the mechanical results will be figured as well as the heat losses:

PROBLEM

Engine data:	
Diameter of cylinder, in.	8.5
Area of piston $(8.5)^2 \times 0.7854$, sq.in.	56.75
Length of stroke (L), in.	18
Clearance, cu.ft.	0.25
Flywheel circumference, ft.	16
Test data:	
Rope brake on the flywheel to load the engine	
Net weight on brake, lb.	93
Speed, r.p.m.	175
Average explosions per min. (E)	80
Mean effective pressure (P), lb.	45
Gas used per explosion, cu.ft.	0.07
Weight of gas per cu.ft., lb.	0.084
Heat value of the gas per cu.ft., B.t.u.	300
One pound of the air at room temperature (68 deg. F.) = 14.2 cu.ft.	
Cooling water used, lb. per explosion	0.13
Cooling water temperature change, deg. F.	65
Temperature of exhaust gases above room temperature, deg. F.	600

To be determined:

1. Indicated horsepower.
2. Brake horsepower.
3. Mechanical efficiency.
4. Cubic feet of gas per hour.
5. Cubic feet of air per hour.
6. Ratio of air to gas.
7. Heat supplied per hour.
8. Heat taken up by the cooling water per hour.
9. Heat in exhaust gases.
10. Heat turned into mechanical energy (i.hp.).
11. Heat turned into useful work (b.hp.).
12. Thermal efficiency of the engine.
13. Balance of the heat losses.

Solution:

1. $$\text{I.hp.} = \frac{PEAL}{33{,}000} = \frac{45 \times 80 \times (8.5)^2 \times 0.7854 \times 1.5}{33{,}000} = 9.27.$$

2. Brake horsepower equals net load on the brake times circumference of the flywheel $\times$ r.p.m. $\div$ 33,000

$$B.hp. = \frac{93 \times 16 \times 175}{33{,}000} = 7.88$$

3. $$\text{Mechanical efficiency} = \frac{\text{brake horsepower}}{\text{indicated horsepower}} = \frac{7.88}{9.27} = 85 \text{ per cent.}$$

4. $0.07 \times 80 \times 60 = 336$ cu.ft. of gas per hour.

5. $$\text{Displacement of the piston} = \frac{(8.5)^2 \times 0.7854}{144} \times 1.5 = 0.593 \text{ cu.ft.}$$

$(0.593 - 0.07)\ 80 \times 60 = 2510$ *cu.ft. of air per hr.*

6. Ratio of air to gas $= 2510 \div 336 = 7.46$.

7. Heat supplied by the gas per hour = 336 cu.ft. $\times$ 300 B.t.u. = 100,800 B.t.u.

8. Heat taken up by cooling water:

Quantity of water used per hour $= 0.13 \times 80 \times 60 = 624$ lb.

Temperature change = 65 deg.

B.t.u. given up to cooling water per hour = 624 × 65 = 40,560 and

$$\frac{40,560}{100,800} = 40.24 \textit{ per cent.}$$

9. 2510 cu.ft. of air per hour ÷ 14.2 = 176.7 lb. of air per hour.

336 *cu.ft. of gas per hr.* × 0.084 = 28.22 *lb. of gas per hr.*

176.7 + 28.22 = 204.92 *lb. of mixture per hr.*

Specific heat of exhaust = 0.245.

Change in temperature of the gas = 600 deg. F.

204,92 × 600 × 0.245 = 30,123 *B.t.u.*

30,123 ÷ 100,800 = 29.88 *per cent.*

10. Heat turned into mechanical energy = 2545 × i.hp. = 2545 × 9.27 = 23,592 B.t.u.

23,592 ÷ 100,800 = 23.4 *per cent.* (*thermal efficiency*)

11. Heat turned into useful work = 2545 × b.hp. = 2545 × 7.88 = 20,054 B.t.u.

12. Net thermal efficiency of the engine = 20,054 ÷ 100,800 = 19.89 per cent.

13. Cooling water loss = 40,560 B.t.u.
Exhaust loss = 30,123 B.t.u.
Heat turned into mech. work = 23,592 B.t.u.
Total = 94,275 B.t.u.

Balance of heat losses = 100,800 — 94,275 = 6525 B.t.u.

6525 ÷ 100,800 = 6.47 *per cent.*

The Deterioration of Engines and Boilers

By Edward Ingham

The question of "wear and tear" of steam-plant apparatus is of importance to the steam-power user, especially where large plants are concerned. Certain parts of a steam engine, constantly rubbing against one another, cause wear. An engine piston wears the walls of the cylinder and the piston rings also gradually become reduced. The rotation of the crankshaft wears the bearings; other parts wear in like manner. The extent of wear taking place depends largely on the engineer in charge, the design of the engine, and the manner in which the engine was erected.

Excessive wear is sometimes caused by the settling of the foundations, throwing the engine out of line. This is sometimes caused by the mortar of the foundations becoming saturated with oil, which has a destructive effect; it will also affect concrete foundations. They should, therefore, be protected from oil by suitable drip oil pans.

If an engine is adjusted too tightly, increased friction and wear, hot bearings, etc., will result; if too slack, the engine may knock and stresses be set up with the risk of incurring a breakdown. The practice of cooling hot bearings by pouring cold water over them is risky and may cause a fracture.

Fatigue of Metal

In addition to the deteriorating influence of "wear and tear," there is the factor of fatigue, which plays a most important part in reducing the working life of a steam engine, and cannot well be avoided. By this is meant the weakening which certain metals suffer when exposed to a large number of repetitions of stress.

Both the piston rod and the connecting-rod of a steam engine are subjected to a tensile and a compressive load at each revolution, the effect of which is to lead to disintegration and weakening, particularly if the range of stress is high. Where only low factors of safety are adopted in the design, the probability of failure and breakdown from fatigue is much greater than where the margin of safety is large. It would be possible to almost entirely do away with fatigue, by making the parts of such strength that the working stresses would be very low, but this would necessitate massive and costly parts; hence in actual practice fatigue is always to be considered. To reduce the risk of engine breakdown resulting from weakened parts by fatigue, it is becoming the practice for some insurance companies and experts to advise owners to renew the more severely stressed working parts, after these have been in use a certain number of years, whether they show signs of weakness or not. Experience has shown that engines do break down from fatigue.

Two beam engines built from the same patterns, were supplied for driving a large textile mill. Both engines were put to work at the same time and under the same conditions. After working for nearly 20 years, the beam of one engine broke. Within a short time the beam of the other engine similarly failed. During the years these engines had been running each beam had made about 200,000,000 oscillations.

Boiler Deterioration

The principal cause of boiler deterioration is the wasting away of the plates, both internally and externally, until they become too weak to safely withstand the pressure to which they are exposed. Internal corrosion is caused by impurities in the feed water, galvanic action, etc. This defect can usually be prevented by adding suitable chemical reagents to neutralize the acid action of the water, or, in the case of galvanic action, by placing zinc blocks in the boiler.

External corrosion is caused by allowing the external plate surfaces to become damp, and can easily be prevented by preventing moisture coming in contact with the plates. Its existence is generally an indication of carelessness and ignorance on the part of those responsible for the maintenance and upkeep of the boiler. There are, however, other influences than corrosion which tend to reduce the working life of a boiler. If the feed water deposits much scale and dirt in the boiler, trouble from overheating, straining and leakage will be experienced, unless special care is given to cleaning and washing out the deposits.

The most that a boiler compound can do is to soften the scale so that it can be readily removed. Unless the water is treated before being fed into the boilers, frequent cleaning is quite as necessary, if not more so, when reagents are used as when not. If the plates be kept free

of scale and deposits overheating will not occur. The presence of a very small quantity of grease in a boiler is likely to cause serious trouble; this is particularly true if the feed water contains deposits of lime and magnesia.

The life of a boiler is influenced by the person in charge. A fireman who allows the fire bars to become bare, so that a large volume of cold air rushes into the furnaces, or who raises steam rapidly and then opens the furnace doors to admit cold air to prevent the safety valves from blowing, is responsible for weakness and deterioration. Some firemen do not allow a reasonable time in which to raise steam and, when laying a boiler off for cleaning or inspecting, will blow off under pressure. It is not uncommon for the more ignorant firemen to actually play cold water over the hot plates immediately afterward. This is bound to cause excessive straining of the plates, and would account for seam troubles.

Even with good working conditions serious defects will appear, if the design and construction are not of the best, or if the boiler has been improperly set. Unless contraction and expansion strains are cared for, deterioration and disintegration will begin as soon as the boiler is put in service.

An experienced inspector can readily detect signs of incipient deterioration before any real mischief is done long before an ordinary engineer not skilled in this particular duty would detect them.

The Cause and the Remedy for Clinkers

By F. Webster

SYNOPSIS—The clinker problem is a slag problem. When analysis of a coal shows presence of impurities in proportions favorable to formation of slag, the proportions may be changed and formation of slag prevented by adding some of the same substances. The usual chemical combinations in slag making are explained with examples. The objections to the presence of sulphur is overestimated; it is sometimes beneficial.

Most firemen have noted the formation of clinkers, and have exercised much mental and physical effort to prevent and to get rid of them. That the burning of some kinds of coal never forms clinkers is well known, and it is also known that with other kinds of coal a large proportion of the incandescent bed of fuel seems to fuse down to a liquid which is often so thin as to trickle into the ashpit. In a locomotive firebox the liquid slag is often so limpid that the strong lift of the draft will raise it from the grates and splash it over the flue sheet and other heating surfaces, where it hardens and becomes a foe to boiler efficiency.

The questions which naturally present themselves are: What is the clinker which sometimes collects in large masses over the grates? Why is it formed by some coals and not by others? What are the remedies, and, finally, can we tell beforehand whether or not a given grade or shipment of coal will or will not clinker? For many purposes it is highly important that the coal burned on a boiler grate will not clinker, and both annoyance and expense may be obviated if reliable tests can be applied before the coal is purchased.

The clinker problem is a slag problem, and to intelligently cope with the question of clinker in a boiler furnace one should understand the principles which underlie the formation of slag.

A glass bottle is an example of a slag which has been made and formed to order. White sand and "salt cake" in the correct proportions are heated together until they unite chemically and form a fluid which we call glass. This is colored to suit the requirements of the trade by adding some suitable material to the mixture before it is heated. Thus, gold makes the ruby-red glass; arsenic, white; cobalt, blue; iron, green and black; magnesium, a violet; uranium, a yellow, etc. In glass making a perfect slag is formed because the proportions of the ingredients are correct and exact treatment is given in the process.

In the boiler furnace, however, the coal furnishes the entire stock as the heat necessary for fusion and slag comes from such impurities in coal as iron, sand, clay, lime, sulphur, magnesia, etc. It is the sand when heated with the lime, iron, clay, etc., that forms the fluid mass like the glass mentioned above, but one that is irregular in composition and varied in color according to the impurities present in the coal. This slag flows over the ash and other ingredients that are not melted, and when cooled, cements the particles together and forms the hard ugly mass which we call clinker. The cementing of the ash by the slag may be likened to the making of a popcorn ball in which grains of corn are stuck together by a coating of molasses. The iron gives the clinker its reddish or brownish color, which is modified by the color of the enveloped particles and other conditions, so that the resulting color may be anything from a white to a black.

Iron and sulphur when present as impurities usually form with coal a compound called pyrites, sometimes called "fool's gold," owing to its yelow metallic appearance. The sulphur may also be in combination with the lime, forming a compound known as gypsum. Speaking chemically, the sand is an oxide of silicon; the clay is an oxide of aluminum; likewise the magnesia and the lime are oxides of the metals magnesium and calcium respectively, meaning that they have united with oxygen to form the rust or ash of those metals.

In order to make a slag, an acid substance must be heated with a basic substance. The action will be to destroy the chemical affinity which each substance has in holding its elements together so that the two substances will unite with each other and form an entirely new compound. The acid substance is the sand, while the basic substances are the clay, lime, magnesia and the oxidized

iron. As sulphur is uncertain it will not be considered for the present. The sand, lime, clay, etc., when heated alone will withstand very high temperatures; in fact, much higher than they are ever subjected to in boiler furnaces. But when mixed together and heated, they will melt easily, and in some cases make a thin and very fluid slag, especially where the mixture is proportioned so as to produce a new chemical compound. But it is important to observe that when either the sand or the base is greatly in excess, then a much higher temperature is required to do the melting; also that sand when mixed with two or more bases will sometimes melt at a lower temperature than where a single base is present. These are very important phenomena in formation of slag because they give us a means of preventing the formation of clinkers in the boiler furnace. Thus, by spreading some crushed limestone or oyster shells over the fire to increase the base, or if the proportion of sand is abnormally high, the fusing point will be higher than the temperature of the furnace and less clinker will form.

Slag formation is best understood when we have the viewpoint of the chemist. This is easily had even by the ordinary reader who does not understand chemistry. The chemist does not recognize any chance work, for he considers the elements as acting upon each other in perfect harmony, resulting in unity and completeness of combination and that nothing is lost in nature, but that changes take place and new compounds are formed, always in definite proportions of the elements, and the sum of the weights of the products is exactly equal to the weight the substances had before the changes took place. Hence in formation of slag nothing is created and nothing originally present can be annihilated.

In chemistry a term called the atomic weight is commonly used. This term expresses the relative weights of the elements of the various kinds in the proportions that they unite with each other to form compounds. An element is a substance, such as gold, sulphur, oxygen, hydrogen, etc., that has never been separated into other substances. As examples of atomic weights, that of iron is 56 and that of oxygen is 16. The combination of iron and oxygen, known as ferrous oxide, which we will consider later when discussing its effect in making clinkers, has a molecular weight of $56 + 16 = 72$; that is, the molecular weight refers to the weight of the compound. Finally, the chemist uses a kind of shorthand in writing the names of elements and their compounds so as to show all the facts in one short expression; thus, Fe stands for iron, O for oxygen, and Si for silicon. Likewise, FeO stands for ferrous oxide, showing that it is made up of equal parts of iron and oxygen; FeS_2 stands for pyrites mentioned above, which is a compound having one part of iron to two parts of sulphur; SiO_2 is silicon dioxide, or sand, which is made up of one part of silicon and two parts of oxygen.

TABLE I.

Elements			Compounds		
Name	Symbol	Atomic Weight	Name	Symbol	Molecular Weight
Aluminum	Al	27	Lime	CaO	56
Calcium	Ca	40	Silica (sand)	SiO_2	60
Carbon	C	12	Aluminum (clay)	Al_2O_3	102
Hydrogen	H	1	Ferrous sulphide	FeS	88
Iron	Fe	56	Iron disulphide (Pyrites)	FeS_2	120
Magnesium	Mg	24	Calcium sulphate (Gypsum)	$CaSO_4$	136
Oxygen	O	16	Magnesia	MgO	40
Silicon	Si	28	Sulphur dioxide	SO_2	64
Sodium	Na	23	Water	H_2O	18
Sulphur	S	32	Calcium Monosilicate	Ca_2O_4Si	172
			Ferrous Monosilicate	Fe_2O_4Si	204
			Magnesium Monosilicate	Mn_2O_4Si	140
			Aluminum Monosilicate	$Al_4O_{12}Si_3$	384
			Ferrous oxide	FeO	72

Table I* gives names, chemical symbols, and the relative atomic weights and molecular weights of substances usually assigned to elements and combinations commonly met with in fuel, ash and clinker in boiler practice.

By monosilicate as noted in the last four items in the table is meant a compound made by the silica, SiO_2, uniting with any base in such a proportion that the amount of oxygen in the base is the same as that in the sand. Hence, it will be seen that two of lime, CaO, or of ferrous oxide, FeO, etc., must be used with the one part of sand, SiO_2, in order to get O_2 in the base. With the clay, Al_2O_3, two parts must be used for every three of sand, SiO_2, so as to get the oxygen in the silicon to balance that in the clay.

The method of finding out by means of slag calculations whether or not a given coal will clinker, and if so why it clinkers and how the clinkering may be prevented, will be understood from the solutions of a few examples.

The slag test is based on the analysis of the coal ash. Thus, the analysis of a certain coal ash is: Silica, 33.5 per cent.; alumina, 24.2 per cent.; lime, 19.5 per cent.; ferrous oxide, 14.3 per cent.; magnesia, 5.7 per cent.; and sulphur, 2.5 per cent. As these various bases will unite with the silicon, the first thing to do is to find out whether or not there is enough silica to fuse all of them, and to see which predominates—the bases or the silica. To get these proportions we must use the molecular weights given in the table, thus:

*The atomic weights quoted by the author are those commonly used for practical computations, though not strictly in accordance with the most recent values employed in chemistry in which the weights are referred to O = 16 and H = 1.008. The figures recommended by the Eighth Congress of Applied Chemistry to be used in all commercial work until 1915 are given below in the table of weights, quoted from "The Engineering and Mining Journal" of Jan. 18, 1913.—Editor.

INTERNATIONAL ATOMIC WEIGHTS

Element	Symbol	Weight	Element	Symbol	Weight
Aluminum	Al	27.1	Molybdenum	Mo	96.0
Antimony	Sb	120.2	Neodymium	Nd	144.3
Argon	A	39.88	Neon	Ne	20.2
Arsenic	As	74.96	Nickel	Ni	58.68
Barium	Ba	137.37	Niton	Nt	222.4
Bismuth	Bi	208.0	Nitrogen	N	14.01
Boron	B	11.0	Osmium	Os	190.9
Bromine	Br	79.92	Oxygen	O	16.00
Cadmium	Cd	112.40	Palladium	Pd	106.7
Caesium	Cs	132.81	Phosphorus	P	31.04
Calcium	Ca	40.07	Platinum	Pt	195.2
Carbon	C	12.00	Potassium	K	39.10
Cerium	Ce	140.25	Praseodymium	Pr	140.6
Chlorine	Cl	35.46	Radium	Ra	226.4
Chromium	Cr	52.0	Rhodium	Rh	102.9
Cobalt	Co	58.97	Rubidium	Rb	85.45
Columbium	Cb	93.5	Ruthenium	Ru	101.7
Copper	Cu	63.57	Samarium	Sa	150.4
Dysprosium	Dy	162.5	Scandium	Sc	44.1
Erbium	Er	167.7	Selenium	Se	79.2
Europium	Eu	152.0	Silicon	Si	28.3
Fluorine	F	19.0	Silver	Ag	107.88
Gadolinium	Gd	157.3	Sodium	Na	23.00
Gallium	Ga	69.9	Strontium	Sr	87.63
Germanium	Ge	72.5	Sulphur	S	32.07
Glucinum	Gl	9.1	Tantalum	Ta	181.5
Gold	Au	197.2	Tellurium	Te	127.5
Helium	He	3.99	Terbium	Tb	159.2
Holmium	Ho	163.5	Thallium	Tl	204.0
Hydrogen	H	1.008	Thorium	Th	232.4
Indium	In	114.8	Thulium	Tm	168.5
Iodine	I	126.92	Tin	Sn	119.0
Iridium	Ir	193.1	Titanium	Ti	48.1
Iron	Fe	55.84	Tungsten	W	184.0
Krypton	Kr	82.92	Uranium	U	238.5
Lanthanum	La	139.0	Vanadium	V	51.0
Lead	Pb	207.10	Xenon	Xe	130.2
Lithium	Li	6.94	Ytterbium	Yb	172.0
Lutecium	Lu	174.0	Yttrium	Yt	89.0
Magnesium	Mg	24.32	Zinc	Zn	65.37
Manganese	Mn	54.93	Zirconium	Zr	90.6
Mercury	Hg	200.6			

The silica unites with the lime to form a calcium monosilicate, or

Sand		Lime		Monosilicate
SiO_2	+ 2	CaO	=	Ca_2O_4Si
60	+	112	=	172

that is,

$\frac{60}{172}$ = about 0.35 of the compound would consist of silica. Likewise, for the clay the silica required is found from the equations:

Sand		Clay		Monosilicate
$3SiO_2$	+	$2Al_2O_3$	=	$Al_4O_{12}Si_3$
180	+	204	=	384

showing that $\frac{180}{384}$ = about 0.47 of the compound would consist of sand; and for the magnesia

Sand		Magnesia		Monosilicate
SiO_2	+	$2MgO$	=	Mg_2O_3Si
60	+	80	=	140,

or

$$\frac{60}{140} = \text{about } 0.43$$

and for the iron

Sand		Ferrous oxide		Monosilicate
SiO_2	+ 2	FeO	=	Fe_2O_3Si
60	+	144	=	204,

or

$$\frac{60}{204} = \text{about } 0.30 \text{ of the compound.}$$

The amount of silica taken care of by all the bases found in the ash will be the sum of the products obtained from multiplying the percentages of the bases in the ash by the factors worked out above, i.e.:

	Per Cent.
By the CaO (lime)	$19.5 \times 0.35 = 6.825$ per cent.
By the Al_2O_3 (alumina)	$24.2 \times 0.47 = 11.374$ per cent.
By the MgO (magnesia)	$5.7 \times 0.43 = 2.451$ per cent.
By the FeO (ferrous oxide)	$14.3 \times 0.30 = 4.290$ per cent.
Silica taken care of by bases in the ash	= 24.940 per cent. of the ash.

Referring to the analysis of the ash, 33.5 per cent. of silica was present, which is enough to take care of the 24.94 per cent. required by the bases and with possibly enough left over to affect the thinness of the slag and prevent the formation of clinker.

Effect of Sulphur

Some engineers charge the formation of clinkers to the sulphur in the coal. This is wrong, for, as a matter of fact, the sulphur will prevent clinker. The reason for this is that iron has a greater affinity for sulphur than it has for silicon, at least it has in a boiler furnace where the temperature is not high enough for their union as is the case in a blast furnace. As previously stated, the sulphur exists in the coal as pyrites, FeS_2, and when the compound is heated to about 1000 deg. F. or more, one part of the sulphur is driven off. This unites with two parts of oxygen from the air and forms sulphur dioxide, SO_2, which is the same as the gas formed from burning a sulphur match. The remaining compound, FeS, is very stable and will not be broken up so as to leave the iron free to unite with the silicon of the sand. As iron oxide and silica form an easily fused and very limpid slag, it follows that the action of the sulphur in keeping the iron from the silicon prevents slag formation, at least insofar as the iron is concerned. An example of a coal ash containing considerable sulphur will show this. Take the analysis of an ash as follows:

Alumina, 14.36 per cent.; ferrous oxide, 14.12 per cent.; magnesia, 19.75 per cent.; silica, 30.16 per cent.; sulphur, 6.4 per cent.

From the values in the table quoted it is to be seen that the amount of iron in the ferrous oxide, FeO is $\frac{56 \times 100}{56 + 16} = 78$ per cent. The iron in the ash = 14.12 per cent. $\times$ 0.78 = about 11 per cent. in ferrous sulphide, FeS, it takes 56 parts of iron for every 32 parts of sulphur; hence, for one part of sulphur it takes 56 $\div$ 32 parts of iron, and for 6.4 per cent. sulphur, as given in the ash, it will require (56 $\div$ 32) $\times$ 6.4 per cent. = 11.2 parts of iron to take care of the sulphur. Referring to the computation given immediately above, it will be seen that the ash has 11 per cent. iron, which happens to be practically the same as that required by the sulphur. Therefore, there will be no iron left to slag with the sand. In other words, the sulphur has killed the best base in the ash for making clinkers. In case the silica is low, there will be little chance to make clinkers with this coal.

The Size Limit of Large Steam Turbines*

SYNOPSIS—The size of the unit is limited by the restrictions of transportation, and by the high cost of exceptionally large forgings and castings. The capacity depends upon the amount of steam which can be passed through the low-pressure blading of this limited size of disk or drum without sacrificing too much to residual energy to induce a rapid outflow.

In the earlier days of power-plant development, when breakdowns were prevalent, security was sought in a minute subdivision of the plant into relatively small units.

In general, the cost of providing for a given aggregate output is the greater the greater the number of units. For this there are several reasons; one important factor is that what may be called the "noneffective" cost of a steam turbine is proportionately much greater the smaller the unit. The cost in question comprises that of the governor and its gear, the valve-gear, the oil pump, the tachometer, and similar accessories. In the case of a 500-kw. unit, the cost amounts to about 45 per cent. of the total construction, falling, in a 1000-kw. unit, to 40 per cent., and in a 10,000-kw. unit to 30 per cent. Hence, even if the "effective fraction" of a complete turbine costs the same per kilowatt for a small unit as for a large one, the total cost would be more with the smaller sizes. Actually, this argument understates the case for the larger unit. In fact, the same casing is sometimes used for a 5000-kw. machine as for a 7000-kw. unit and at the same speed, so that the turbine costs proper are almost identical. Some saving results from a smaller condenser being required with the smaller output, but the floor space occupied will be larger the greater the number of units, and the efficiency of small prime movers is markedly less than that of large ones.

To this rule the internal-combustion engine forms an

*Abstract from "Engineering," London.

exception, the efficiency attained with a 60-hp. engine being about as high as with an engine ten or twenty times its size.

With some forms of prime movers other than the gas engine, the limit of size is less definitely circumscribed by purely mechanical considerations. Theory shows that a limit must exist, since all prime movers are ultimately subject to the law that, while the output increases as the square of the dimensions, the weights involved increase as the cube. For the present, anyhow, this consideration hardly affects the question as to what is the limiting size of a steam-turbine unit. The latter is determined by difficulties of transport and by the high cost of exceptionally heavy castings and forgings. If a power station is intended to furnish a three-phase supply at 25 cycles, the turbo-alternator must run at either 750 or 1500 r.p.m. If the former be chosen, the limit of size is definitely fixed by the question of transportation, the loading gage on British railways restricting the diameter of a drum rotor over the blade to about 8 ft. 6 in. and the diameter of a disk to about 13 ft.

An interesting point which then arises is the maximum output possible with rotors of the dimension stated, and depends essentially on two factors, the centrifugal stresses and the vacuum obtainable. Condensing plants have been so much improved that with a barometer of 30 in. a vacuum of 29 in. should be realized during most of the year. As delivered from an efficient turbine, the volume of 1 lb. of steam at a 29-in. vacuum is 600 cu.ft., making an average allowance for the wetness of the exhaust steam. If this steam is allowed to have an axial velocity at discharge of 440 ft. per sec. and the blade length is limited to one-fifth the mean diameter of the blading, the kilowatt output of the turbine cannot exceed the square of the mean diameter in inches of the last row of blades, assuming the low steam consumption of 11.5 lb. per kw.-hr. If it is assumed that the last row of blades is carried on a disk 13 ft. in diameter over blade-tips, the maximum output possible from a single-flow turbine operating with a 29-in. vacuum and a "carry-over"* loss of about 4 B.t.u. would be about

$$130^2 = 16{,}900 \ kw.$$

By admitting a carry-over loss of 9 B.t.u., this output could be increased to about 25,000 kw. If the vacuum were limited to 28 in., the possible output would be 33,000 kw. with a carry-over loss of 4 B.t.u., and about 28,000 kw. with a carry-over loss of about nine heat units.

Allowing for a reheat factor of, say, 1.05, the heat available with steam at 200 lb. absolute and 200 deg. F. superheat, expanded down to 28 in. vacuum, is about 391 B.t.u. per pound; while if the expansion be carried to 29 in. vacuum the corresponding figure is about 428 B.t.u. An exhaust loss of 4 B.t.u. is about 1 per cent. of the total energy available, and one of 9 B.t.u. per pound about 2¼ per cent. To get 33,000 kw. out of a single-flow turbine with a 29-in. vacuum, would necessitate an axial velocity at discharge of about 880 ft. per sec., and the carry-over loss would amount to nearly 16 B.t.u. An increase of vacuum from 28 to 29 in. would still result in a saving of steam since the heat available on expansion to the lower limit is about 37 B.t.u. more. An attempt to get 48,000 kw. out of the turbine with a 29-in. vacuum, however, would be futile, as the carry-over losses would be so greatly increased as to cancel almost all of the difference in the heat available with a 28-in. and a 29-in. vacuum.

There would, of course, be no difficulty in running a wheel of the size proposed at 750 r.p.m. In fact, experience with a DeLaval turbine shows that the speed limit might be raised to 1100 r.p.m. without exceeding limits of safe stress in practice. A 300-hp. DeLaval wheel has a mean diameter of 30 in., the blade being about 1.25 in. in usable length, and the speed 10,600 r.p.m. If every part of the wheel were increased in direct proportion to a mean diameter of 130 in., the stresses would be as before, provided the revolutions were reduced in the ratio of 30 to 130 (to about 2440 r.p.m.). The blade length would then be 5.5 m. If the length of these blades were next increased to 26 in., their weight and the stresses in them would increase about 4.75 times. To reduce the stress to its original limit the speed must be divided by $\sqrt{4.75}$, becoming 1125 r.p.m. If the ratio of blade speed to steam speed were the same with a 26-in. blade as with the 5.5-in. blade, the bending stresses produced by the steam which drives them would be the same as before and the margin of security as great as in the original DeLaval wheel. This increase of blade length would also involve a diminution in the size of the wheel disk, so that the total stresses in the latter would be less than they were in the original wheel. By constructing the low-pressure portion of a turbine on the double-flow system the limiting outputs just stated may be doubled and hence large outputs are mechanically feasible in single units.

For the present, the practical limit for a turbine running at 750 r.p.m. is probably about 25,000 kw., and if of the drum type, questions of rail transport make it necessary to construct a motor for such an output on the double-flow system. The castings present less difficulty, as they can be built up in sections. The total weight of such a machine would be between 250 and 300 tons, that of the heaviest part to be lifted being between 30 and 40 tons. The sizes of the forgings required would be up to the limit of what can now be obtained, and the cost per ton of the large forgings and castings is considerably more than those of more moderate size. It is open to doubt whether units of this size are, save in exceptional cases, more advisable than those of about one-half to two-thirds the capacity in question; running at the alternative speed of 1500 r.p.m., the last row of blades might then have a mean diameter of 85 in. or a tip diameter of 8 ft. 6 in. and the output without extravagant losses to the exhaust might run up to fully 14,000 kw. In the double-flow type the highest economy could be attained with quite moderate stresses. The limit is, of course, the same for impulse as for reaction turbines. The output per ton is much more at 1500 r.p.m. than at 750, which is easily understood when it is remembered that the efficiency of a steam turbine depends largely on the "velocity ratio" or the ratio of blade to steam speed, which again with given steam conditions, depends on the "coefficient" or the revolutions^2 × mean diameter^2 × number rows of blades. For a stated number of revolutions, this coefficient is obviously proportional approximately to the volume of the turbine casing. It is thus seen that the volume of the turbine casing and the weight is only about one-quarter for 1500 r.p.m. of that required for 750 r.p.m. The smaller weights to be handled at the higher speed means,

*The carry-over loss is the loss in energy, expressed in heat units, represented by the velocity and weight of steam passing out of the last row of blades at the vacuum carried.

moreover, a much lighter construction of the engine house, smaller cranes and less massive foundations.

Apparently, there would be no difficulty in constructing an alternator of this output to run at the speed named. Last year, the Westinghouse Co. built alternators to run at this speed with an output of 20,000 kw. Since the output of an alternator varies nearly as the inverse square of the revolutions, or by the same law as that of the turbine, it should be easily practicable to run a unit developing 12,000 to 14,000 kw. at 1500 r.p.m.

In view of the ease of carriage, the light weights to be handled and the facility with which the turbine could be dismantled when required, it would seem that the smaller high-speed plant is really much to be preferred to the larger, and since the weight per kilowatt is less, the cost should also be lower, particularly in view of the high price of large castings and heavy forgings, to which attention has already been called. Moreover, with the large structure, distortions due to its own weight and to temperature variation, are more pronounced, making it necessary to adopt clearances proportionately larger in the larger units, so that the smaller machines might prove the more economical under test, though data on this point are still lacking.

Powdered Coal under Boilers*

By William A. Evans

Early experiments with powdered coal amounted to a general education and the discovery of the elementary principles upon which it operates. Failures were then primarily due to defects in pulverizing apparatus and that for feeding the powdered coal to the furnace. The principles of operation have become well established and the apparatus well standardized. The elements of good powdered-fuel combustion consist of finely ground coal, 90 per cent. through standard 100-mesh screen, thorough mixture of coal and air before entering the furnace, and good control of both coal and air. With these elements worked out properly, powdered fuel has shown marked economies on many furnaces and the results obtained are worth striving for in the case of boilers.

To the writer's knowledge, but two types of boiler have shown any success. Several attractive results have been obtained on horizontal return-tubular boilers, a battery of six having been operated for eight years at one plant and requiring but one man to run the entire plant. Of the water-tube type of boiler, none of the standard makes has shown any permanent results, although there is a boiler designed specially for powdered coal that, according to reports, is giving satisfactory commercial results. The return-tubular and this special boiler have combustion space for the amount of fuel burned much in excess of what is provided in most water-tube boilers. This large space seems to be the one essential.

The points of furnace design which are likely to bring about the successful use of this fuel under boilers are: Large combustion space, firebrick lined with no exposed boiler surface; means for disposing of ash; design of furnace, water cooled, that will insure a reasonable length of life to the firebrick setting, and provision for firing from a cold boiler without the use of auxiliary power to run the pulverizer and air supply.

*"Power," Jan. 13, p. 69.

In most experiments with boilers using powdered coal these four essential features of furnace design have been disregarded. Powdered coal requires a high temperature for ignition and for maintained combustion; at all parts of the furnace it should be at least 1800 deg. F. As these temperatures cannot be maintained and the combustion completed in contact with boiler-tube surfaces, a large space not in contact with the tubes has to be provided.

For the complete burning of powdered coal a space of one cubic foot for each boiler horsepower developed should be provided, because of the difficulty with which high-volatile coal burns on grates. Volatile gases escape from the grates, and unless there is a hot arch above and plenty of space, the gases escape to the tubes, where the flame is stifled with resultant smoke. The volatile matter is the most difficult part of the coal to burn with grate fires, but it becomes the more easily burned in the case of powdered-fuel combustion. This is because combustion of the coke occurs while suspended and traveling. In a hot furnace the volatile matter burns promptly while the coke burns as it travels forward, and the time required for combustion depends upon the size of the particle. The length of travel of the flame before it reaches the water tubes of the boiler should be such as to insure complete combustion, both volatile and fixed carbon, before it reaches the boiler surface. Large space then (one cubic foot for each boiler horsepower (maximum) is one of the first requirements of a boiler furnace using this coal. This space can be made doubly effective by causing the flame to make a double travel; that is, forward and backward, or up and down within the space, depending upon the design and local conditions.

Probably the most troublesome feature of powdered-fuel combustion under boilers has been the handling of the ash. When combustion is perfect, with the boiler operating at capacities required in present-day practice, heat is developed much above the fusing point of the ash or the brick, and both form a heavy slag hard to remove. In metallurgical furnaces this feature is taken care of in the slagging of other impurities, but fused ash in the boiler furnace is not so easily cared for. As it moves very sluggishly at a temperature of 2500 deg. and will become solid at 1200 deg., it is, therefore, difficult to remove, for as soon as any door is open for scraping out, it clings to the brickwork with a tenacity difficult to realize except after experience. It may be possible that a flux can be used to make this ash more fluid at low temperatures with small boiler capacities and exceptionally good coal, but the writer questions its practicability on large boiler capacities and on all grades of coal. He further believes that the ultimate solution of the use of powdered coal in boiler furnaces will include a positive means for continuously removing the ash.

In metallurgical work it is customary to frequently rebuild the furnaces, say, every eight to 12 weeks. In using powdered coal in these furnaces the life of the brickwork is somewhat reduced, usually requiring rebuilding every six weeks. Frequent rebuilding of boiler furnaces is highly objectionable, and the high temperatures of powdered coal will certainly destroy the best setting unless some new provision is made. It has been suggested that temperatures in the furnace be reduced by introducing excess air, but this is not practicable, as it would reduce the efficiency of the boiler. On the Bet-

tington boiler as specially designed for powdered coal, the brickwork is maintained by the use of water-cooling tubes, the bricks being specially made to fit around the tubes. It would seem essential that furnaces be built with all the walls cooled by water tubes, the water in which is in circulation with that in the boiler.

The matter of starting up from a cold boiler without auxiliary apparatus is, of course, possible of several solutions, and does not affect the primary success of the boiler in the burning of powdered coal. Fuel oil or gas might be used for getting up steam, or a grate could be incorporated in the design to permit of hand firing.

The features suggested necessarily require an elaborate change in boiler setting. The writer knows of but one case where any such elaborate change was made and that did show very intense heat with good combustion, but no provision was made for maintaining the brickwork, so it failed. The reason for the present-day lack of success with powdered coal under boilers is that each attempt has been made without any definite knowledge of what had previously been done or of the failures of others. Many attempts have been made by innocent purchasers of apparatus sold by ambitious promoters. In these cases the promoter knew nothing but the fact that powdered coal was giving success in some industries and that it ought to work to considerable advantage under boilers. Even if he knew that the redesigning of the setting was necessary or desirable, he would promote the sale by suggesting some slight change in the existing setting, hoping that enough would be developed to encourage the purchaser to continue to the ultimate success of the installation and education of himself.

It is fair to expect that, if a combination of the best elements of coal grinding, coal and air control, large combustion space, means for ash removal and brick maintenance be made in applying powdered coal to a boiler, there will be some success, and the economies already proved will be on the road to a commercial reality.

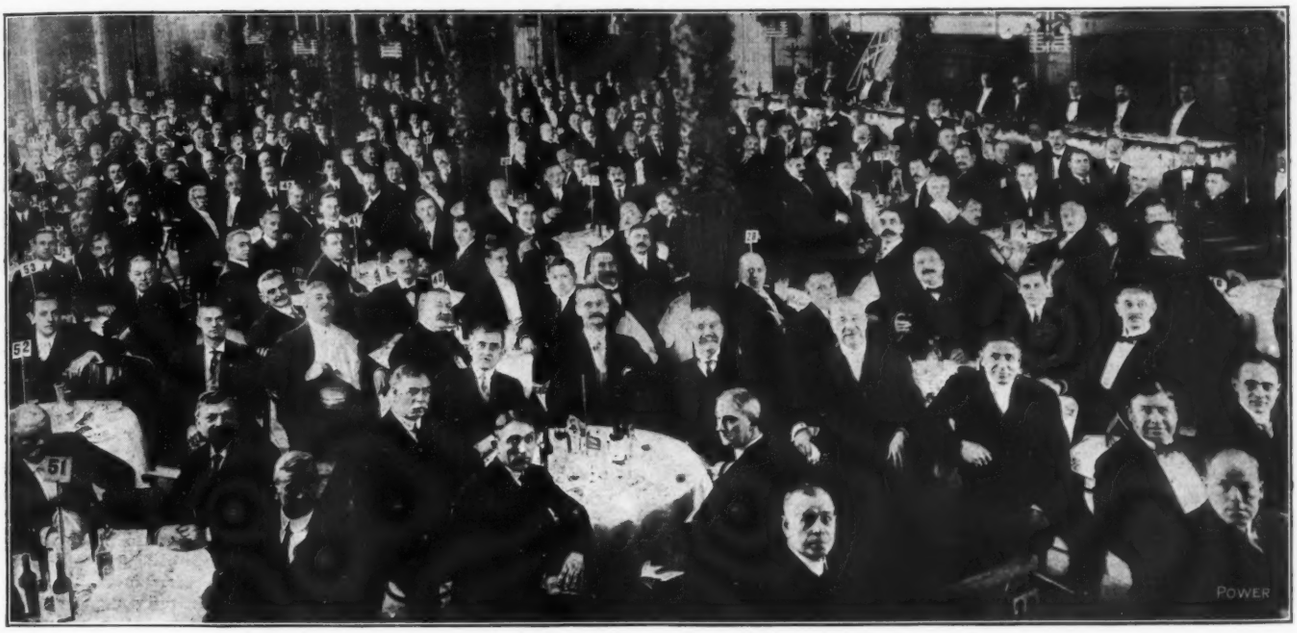
There is a good field for the use of powdered coal and we may expect to see it further developed.

School Engineers Banquet

The third annual banquet of the Engineers of Public Schools of Greater New York, was held in the Broadway Central Hotel, on Saturday evening, Feb. 7.

Hon. M. S. Stern, commissioner of education, commended the work of the engineers and stated that he was especially pleased to report that in over six years only four men in nearly 600 were found guilty of negligence of duty. F. G. McCann, engineer for the commission, told of the need of certain classes of equipment and expressed regret that those needs were not filled more rapidly.

Charles H. Bromley, associate editor of "Power," outlined recent progress in the power-plant field and urged the members to keep pace with it. They are primarily engineers, their janitor duties being incidental. Suggestions were offered to enable the men to perform their part in the greatest of school systems, a system which has about 570 schools, 20,000 teachers, 700,000 pupils and over 500 janitor-engineers.



THE ENGINEERS OF PUBLIC SCHOOLS OF GREATER NEW YORK

Samuel Donnelly, ex-commissioner of education and long connected with the school system, contrasted the crude work of years ago with the efficient methods now practiced.

John E. O'Brien, counsellor for the engineers, in speaking on the workingman's compensation act, said that he believed it applied to the janitor-engineers. Coroner Timothy J. Healy and national president of the Eccentric Association of Firemen commended the members on their splendid organization. Other guests were Commissioner of Education Lavelle and J. B. Hamlin, editor of "School." An enjoyable entertainment was given by Billy Murray and the Dixie Quartet through the courtesy of Jenkins Bros.

Fatal Marine Explosion

The steamship "San Gregorio," largest oil-tank vessel afloat, came into Quarantine, N. Y., on Feb. 5, with her flag at half mast and reported one dead in the ship's company, another dying and two seriously injured. On the evening of Feb. 2 a steam chest had burst, causing the death of William Kemp, an assistant engineer, and scalding nearly all the men in the engine room. Kemp was literally boiled to death, according to Capt. J. E. Grey, of the "San Gregorio."

The "San Gregorio," which sailed from Rotterdam, Jan. 19, had experienced heavy weather and was still in a heavy gale on the night when the accident happened. With the bursting of the steam chest, Kemp, so the men who were with him said, ran back to shut off the steam. He was met with the full force and felled in his tracks. The other men made a dash for the upper deck. In running over the gratings and up the iron stairways some of them fell and were pulled along by their companions. Capt. Grey said that there were many heroic acts.

Kemp's body was found after the steam had been shut

off. His face was unrecognizable. They buried him at sea at sunrise the following morning. The three badly scalded men were placed in an improvised hospital and were there when the "San Gregorio" came in.

The "San Gregorio" is owned by the Eagle Oil Transport Co., of London, and came in ballast. She has a capacity of 100,000 barrels.

Rate Regulation News

One of the most sweeping reductions in power rates which has been effected since the Railroad Commission was organized in California has just been made and will go into effect March 1, 1914.

The Southern California Edison Co. has just filed with the Railroad Commission a revised schedule reducing the rates for electrical power covering practically the entire southern part of the state. This reduction is the result of several weeks of negotiations between representatives of the Edison company and the Railroad Commission. About a year ago, after informal negotiations between them the company put into effect throughout the southern part of the state a maximum lighting rate of 8c. per kw.-hr. The rate, theretofore, had averaged between 9 and 10c. per kw.-hr. The effect of the reduction to 8c. amounted to a saving of approximately $240,000 per year.

Further negotiations have secured a second reduction in power rates. The new schedule just filed provides for a maximum lighting rate of 7c. per kw.-hr. and make an immediate saving to the patrons of the Edison company of at least $120,000 per year. It is estimated that the ultimate effect will be a general saving to patrons of electric energy of at least $200,000 per year.

Investigation before the Public Utilities Commission of Idaho of the rates charged for electric energy served by the Great Shoshone & Twin Falls Water Power Co., the Beaver River Power Co., and the Idaho Light & Power Co., has been ordered, commencing Jan. 26. This is the result of a complaint filed against the former company by the trustees of the city of Wendell, which charged discrimination in rates.

The Beaver River and the Idaho Light & Power Companies are given the choice of participating in the investigation, either as plaintiffs or defendants. These three are virtually in control of the Southern Idaho electrical field and are bitter rivals. The complaint of the Wendell trustees alleged that the Great Shoshone & Twin Falls Co. was serving electrical energy to the towns and cities of Mountain Home, Glenns Ferry and Gooding at a lower rate than to consumers of Wendell. The Great Shoshone Co. denied this and alleged that the Idaho Light & Power Co. and the Beaver River Co., which are serving the same cities and towns and are its rivals, are doing so at a loss. It also charged the two latter companies with instituting the complaint.

Recent Court Decisions

Digested by A. L. H. STREET

Reservation of Title by Seller of Machinery—Where a stationary engine is sold to a contractor, the seller knowing that it is to be installed by the contractor in a power plant, is not entitled to reclaim the engine from the owner of the plant after it has been so firmly affixed to the plant that it could not be removed without injury to the premises, although the engine was sold under a contract providing that title should remain in the seller until payment of the price; the owner of the plant having paid the contractor 90 per cent. of the value of the engine, without knowing that the seller had so attempted to secure payment of the purchase price. (Iowa Supreme Court, Hooven, Owens, Rentschler Co. vs. City of Atlantic, 144 "Northwestern Reporter" 635.)

SOCIETY NOTES

On Jan. 29 the American Institute of Boiler Inspectors held its meeting at the Engineering Societies Building, New York City, and elected the following officers for the ensuing year: President, James Gillespie, Royal Insurance Co., vice-president, Robert Thomson, Travelers Insurance Co.; secretary, J. H. Pollard, Fidelity & Casualty Co.; treasurer, George Turnbull, Globe Insurance Co. James H. Kinkead was elected chairman of the executive and educational board. The institute will hold its annual dinner on Feb. 21, and every effort is being made to have the occasion exceed all former dinners.

The first annual convention of the Mountain States Ice Manufacturers' Association was held at the Albany Hotel, Denver, Colo., Jan. 22-23. Among the papers read and discussed were "Vail's New Type Cylinder Condensers," H. G. Venemann; "Side Lines for Small Plants," J. F. Vandermark; "Raw Water Ice," James Allan. On Thursday morning, Jan. 22, the members visited the plant of the Colorado Ice & Cold Storage Co., and inspected the largest storage room in the world holding manufactured ice. In the evening there was a theater party. A visit was made on Friday to the ammonia works of the Western Chemical Co., which tendered the visitors a luncheon. At 6:30 there was a banquet at the Albany Hotel.

The first annual meeting of the Compressed Gas Manufacturers' Association was held on Thursday afternoon, Jan. 29, at 25 Madison Ave., New York. The retiring president in a brief address reviewed the activities of the association during 1913, and reports from standing and special committees were submitted and read. The following were elected as the executive board for 1914: J. B. Greiner, J. C. Minor, Jr., A. A. Heller, Justin G. Sholes, Hugo Lieber, C. J. Lilienthal, H. E. Sturcke, W. A. Johnston, G. McM. Godley, Eugen Becher, Geo. S. Haydock, J. T. Stewart, Otto S. King, A. Cressy Morrison, Franz Hirschland. The board subsequently organized and elected as officers for 1914: President, Hugo Lieber; first vice-president, J. B. Greiner; second vice-president, A. Cressy Morrison; secretary and treasurer, John J. O'Rorke. The outgoing executive board entertained the members of the association at an informal dinner at the Manhattan Club, Twenty-sixth St. and Madison Ave., in the evening; covers were laid for 60. Dr. Hugo Lieber presided.

PERSONALS

L. B. Stillwell, New York City, has been named by the Secretary of the Treasury as consulting engineer in the construction of a government power plant for Washington, D. C., to cost $1,500,000. It will furnish light, heat and power to all government buildings, including the White House.

Walter E. Housman and Hans E. Seidl have formed a partnership to operate under the name of Seidl & Housman, 901 Swetland Bldg., Cleveland, Ohio. The firm will do a consulting engineering business along the lines of public utility work and mechanical and electrical engineering. Mr. Housman was for many years power expert with the United States Steel Corporation and Mr. Seidl has been associated with public utility work as consulting engineer for a number of years.

Harold Almert, for the past five years manager of the department of examinations and reports of H. M. Byllesby & Co., has severed his connection with that firm to engage in consulting engineering practice on his own account, with offices in The Rookery, Chicago, Ill. Mr. Almert is just completing his twentieth year of work in the organization, financing, design construction, operation and management of public utilities, and for several years has valued or passed on investments for new projects, consolidations, reorganizations or extensions to existing properties of from one to two hundred million dollars, annually. As assistants Mr. Almert will have a staff of well seasoned specialists in mechanical, electrical, hydraulic and gas engineering, appraisals, rate investigations, accounting and efficiency work who, by their training and experience, are experts.

NEW PUBLICATIONS

COAL WASHING IN ILLINOIS. By F. C. Lincoln, of the department of mining engineering, has just been issued as Bulletin No. 69, by the Engineering Experiment Station of the University of Illinois.

A great amount of data, gathered from experiments made in the mining laboratory of the university, personal visits to the various coal washeries in the state, and a thorough search of the scattered literature on the subject, have been compiled and tabulated. The bulletin also contains an article by S. W. Parr, "Moisture in Washed Coals," and is a summary of tests made at the experiment station on carload lots of various washed coals. Copies of Bulletin No. 69 may be obtained upon application to C. R. Richards, acting director of the Engineering Experiment Station, University of Illinois, Urbana, Ill.